Behaviour Observed in Multiple Schedule Components: Implications of data for theories of contrast

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Abstract

Direct Interaction theories of Herrnstein and later Williams and Wixted see contrast as due to the direct effects of reinforcement in one component on responding in another component despite temporal separation in the multiple schedule. Competition theories of Staddon and later McLean and White view responding in a component as independent of reinforcement in the alternating components, but rather a result of competition among competing responses in the same component. Hence other behaviours and other reinforcers mediate the effect of reinforcement in one component on responding in the alternating component.

A key area of contention between theories is when reinforcement in one component of a multiple schedule is made independent of responding, or is provided with non-contingent signals. Here the traditional effect has been a decrease in responding in the non-contingent condition, however reinforcement remains constant. Williams and Wixted argue that since the animal is free to engage in the same behaviours in the non-contingent procedure as in extinction, competition theories must predict contrast. However McLean claims that contrast will occur in this procedure only if behaviour in the non-contingent condition is maintained by extraneous reinforcers (thus if that behaviour is maintained by food reinforcement, or by reinforcement signals, contrast will not occur).

Multiple Schedules were used in an arrangement that produces systematic variation in response rate in the varied component while firstly maintaining reinforcement levels and subsequently removing reinforcement in the varied component. Behaviour during the last three sessions of each condition was recorded using a video camera allowing analysis of behaviours associated with different reinforcement conditions. Results suggested that non-contingent reinforcement, and non-contingent signals, maintain behaviours that occupy the animals time in the varied component to a similar extent as the traditional key peck response when reinforcement is contingent on responding. Subsequently these behaviours diminished with the introduction of extinction. The results support competition theorist's accounts, discrediting one vital criticism of competition theories by Williams and Wixted. The wider implications of the study are discussed, and suggestions for future research are proposed.

Introduction

QUANTIFYING BEHAVIOUR INTERACTIONS IN SCHEDULE RESEARCH

After the publication of Ferester and Skinner's Schedules of Reinforcement (1957) schedule research became a common part of operant research. A schedule of reinforcement is a rule used to govern presentation of reinforcing stimuli, and the way these reinforcers are delivered is now acknowledged as being among the most powerful determinants of an individuals behaviour. The effects of a schedule are observable, systematic, and orderly in all individual organisms, and these effects are replicable both within and across species. In fact so accepted now is this notion that a failure to find the expected patterns of behaviour indicates inadequacies in the experimental control or design.

Ferester and Skinner described patterns of behaviour in pigeons resulting from various schedules, thus they treated the schedule itself as discrete subject matter. Since their work a variety of more complex reinforcement schedules have been explored in the animal lab, particularly those that combine two or more 'components' into a single compound schedule. Each component governs the presentation of reinforcement during the presentation of a distinct stimulus that signals to the animal which component is operating. In addition these components can be signaled on different keys, either concurrently or in succession. By operating more than one component the animal is provided with response alternatives that allow researchers the option of studying a wide variety of choice paradigms in the operant chamber.

There are two ways to explore the effect that reinforcement schedules have on response alternatives. Given that the animal will respond to each of the two schedules, provided there is some reinforcement incentive to do so, the experimenter has the option of examining either the absolute response rates in each of the components, that is how often the animal responded to the different stimuli. Or alternatively the relative response rates can be examined by checking what proportion of the total number of responses made across the session were made to a particular stimulus.

One of the most important questions to come out of schedule research has been the question of how different schedules interact when their availability is either concurrent or temporally closely related. In the operant lab different schedules can operate on a single animal in a single experimental session by arranging the schedules either simultaneously or successively. Different schedules are referred to as schedule components in this situation. In a concurrent schedule an animal is presented with two (or more) response alternatives each being reinforced according to its own schedule (which may be the same). The animal then is presented with a choice between different components and can demonstrate that choice via its distribution of responses.

In a multiple schedule the components alternate successively, thus when one component is operating the other (s) is unavailable. The animal's choice therefore is more restricted as only the one response alternative exists, although the animal always has the option of engaging in activities that are not reinforced by the experimenter, such as scratching. The matching law is a mathematical equation that describes well how an animal will distribute its responses in the concurrent schedule arrangement. The

proportion of responding to a schedule will closely match the proportion of reinforcers that are obtained through that schedule. However although 'matching' may be the standard pattern in concurrent schedules, in multiple schedules response rate changes are always less extreme than the reinforcement ratio changes that invoked them. This phenomenon, known as undermatching, is presumably due to the temporal separation of components in the multiple schedule.

Despite undermatching however, it is now universally accepted that response rate in a multiple schedule is a function of the relative rate of reinforcement, at least to a first approximation (Williams & Wixted, 1986). The generalized matching law (proposed by Lander & Irwin, 1968; Baum, 1974 and given in Equation 1) has described the relationship between response rates in a multiple schedule with considerable accuracy. It is a simple power function relating reinforcement ratios to response ratios.

$$\frac{B_1}{B_2} = b\left(\frac{R_1}{R_2}\right)^a \qquad (1)$$

B and R represent responding and reinforcement respectively with their accompanying subscripts representing component 1 and 2. The bias (b) and sensitivity of response ratios to reinforcement ratios (a) are estimated by fitting a straight line to the data after a logarithmic transformation. While the accuracy of these fits has been shown to be considerably precise the equation has the limitation of only providing a description of relative rates of responding in a component. Thus the equation offers no way of

determining absolute response rates which some commentators (see for example Williams & Wixted, 1986) claim to be of more fundamental importance.

One perplexing behavioural phenomenon, evident in both multiple and concurrent schedules, that any absolute response rate equation will have to account for is behavioral contrast. This has been one of the most heavily investigated topics in operant research over the past three decades. Behavioural contrast is observed when responding is maintained separately by two or more schedules. Since the initial demonstration of contrast by Reynolds (1961), the literature has grown to such an enormity that the area appears to have exhausted itself. However despite this there remains no conclusive answer to the contrast puzzle, that is there is no answer as to why, despite reinforcement rates remaining constant in a component, an organism's response rate increases in that component when conditions in accompanying components are altered. There is, therefore, no validated answer to the more general question of what is the controlling factor in schedule interaction.

BEHAVIOURAL CONTRAST

Emergence of Behavioural Contrast in Behaviour Analysis

In 1961 Reynolds found behavioural contrast using a two component multiple schedule, in what is now a classic demonstration of the phenomenon. Reynolds' baseline consisted of equal variable interval (VI) schedules in both components. Following initial training,

conditions in one component (the "varied" component) were then changed from variable interval to extinction while the other component remained constant (hence the "constant" component). In the varied component response rate decreased rapidly as the schedule no longer reinforced responding, and since the contingency between responding and reinforcement no longer exists this change in behaviour needs no explanation. Contrast occurs in the constant component, which has undergone no change. In this component responding to the stimulus increased when the conditions were altered in the varied component. This behaviour lacks a logical nature given that the constant component was an interval schedule, therefore any increase in responding is unlikely to result in an increase in reinforcement. Prior to this clear demonstration a similar effect had been referred to in the literature. Pavlov (1927 pg188) referred to a process of positive induction in which salivation on an s_+ trial was greater if the previous trial was s- as opposed to another s_+. Skinner (1938 pg175) subsequently referred to the induction process as contrast with Reynolds giving it its full name of behavioural contrast.

Many of the features of Reynold's 1961 experiment have become standard parts of investigations into contrast. Firstly the reinforcement schedule in the constant component is usually a variable interval arrangement where reinforcers are set up according to random time intervals and then are delivered with the next response. The varied component is also often a VI and the change is to extinction (EXT).

While behavioural contrast has also been demonstrated consistently in concurrent schedules (see Catania, 1963) the present work will focus on contrast produced in multiple schedules. The reason is that in a multiple schedule the alternative responses

are never available at the same time thus the responses are not competing with each other directly for the animal's time. Since we have eliminated this possible explanation we can view contrast in a more 'pure' form.

Subsequent Demonstrations of Behavioural Contrast

Reynolds (1961) demonstrated contrast by decreasing the reinforcement frequency in the varied component resulting in an increase in responding in the constant component. While this is the standard demonstration it is only one type of contrast, called positive contrast. That is, the effect of the manipulation is a decrease of reinforcement/responding in the varied component and an increase in responding in the constant component. The opposite of this, increasing reinforcement/responding in the varied component, also produces contrast. Here the effect is termed negative contrast as the outcome is a lowering of responding in the constant component.

Most theories of contrast view positive and negative contrast to be a function of the same, but symmetrical, mechanism. While there is some suggestion in the literature that this may not be the case (see McSweeny and Melville 1993) the current paper will focus on positive contrast since that manipulation is most common in the literature. There is another type of Contrast mentioned in the literature that is important to the present paper. Local Contrast studies measure response rates at different intervals throughout the one component. Results discovered through this line of research have important implications in evaluating theories and will be discussed more fully later.

There has been a number of varied component reinforcement conditions that have been found to produce contrast following initial training. All the manipulations involve changing the reinforcement conditions in the varied component to a less desirable alternative. This can be either a decrease in rate of reinforcement received (as in Reynolds, 1961), a decrease in the amount or quality of the reinforcement received (see Richards, 1972), or the addition of a positive punishment (such as electrical shocks following responding, see Terrace, 1968). Much of the research in contrast over the past three decades has been aimed at differentiating the effect of lowering the reinforcement rate, and subsequently lowering the response rate, in the varied component. Because in the initial demonstration both moved together, either one, or a combination of both could be responsible for contrast. Therefore by manipulating only one of these variables and examining the effect a clear picture could emerge as to the antecedents of contrast.

This line of research has produced some contentious findings. The following studies have all used procedures that allow response rate to decrease while reinforcement rate remains constant. This can be achieved via a number of methods. Firstly signaling the availability of reinforcement in the varied component makes responding in the absence of the signal (which in effect is now an extinction component) unnecessary. Secondly, by reinforcing intervals between responses, adjusting the inter response period to ensure the overall reinforcer rates remain constant, while due to long inter response periods being reinforced the overall response rate is lowered. Or thirdly by delivering reinforcers independent of the animals responding thereby requiring no responding to receive the same levels of reinforcement. There is some evidence that introducing a Differential Reinforcement of Low responding (DRL) procedure produces

contrast from studies by Terrace, 1968; and Weisman, 1969. However contrary to this Boakes, Halliday, and Mole (1976) failed to observe contrast in a replication of the above studies. Likewise Boakes et al. failed to observe contrast following the introduction of a Differential Reinforcement of Other behavior (DRO) procedure which had produced contrast in an earlier study by Weisman (1970). Finally there has been a number of studies that have demonstrated contrast subsequent to signaling reinforcement on a VI, FI, and DRL procedure in the varied component (see Brownstein and Hughes, 1970; Wilkie, 1973). Once again conflicting results (that is no contrast) have been reported by Williams, 1980; and Gutman and Fenner, 1982.

The one change in reinforcement conditions that reliably fails to produce contrast is the introduction of a Variable Time (VT) schedule in which reinforcement is delivered independent of the animals behaviour (see Halliday and Boakes, 1974). Figure one shows data taken from Nevin (1973) showing responding in the constant component when conditions in the varied component are different.

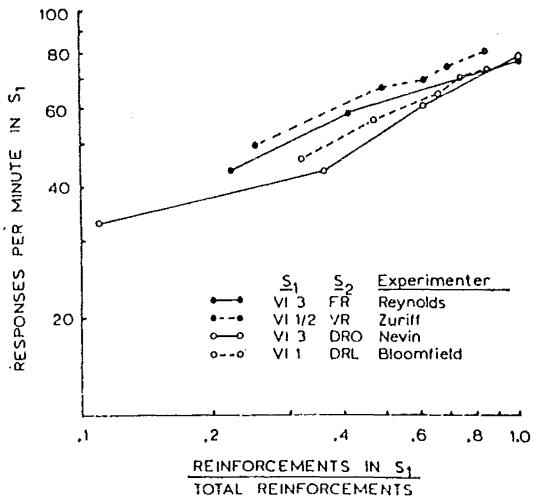

Figure 1: Figure from Williams (1983) who presented data taken from Nevin (1973) showing the results of several contrast experiments in which the schedule in the altered component was different. Response rates are from the constant VI components. Note that both the abscissa and ordinate are in logarithmic units.

Given that the different types of schedules that are shown in Figure 1 are likely to produce different response rates in the varied component, yet responding in the constant component seems the same in all cases, it would appear that the relative rate of reinforcement in the varied component is the controlling variable of contrast. The finding of no contrast when a VT schedule is used supports this conclusion. Here relative reinforcement undergoes no change while response rate falls away rapidly. No change in the constant component suggests that the response rate in the varied component, in isolation, is not a determiner of contrast. However whether changes in relative reinforcement alone produces contrast can be called into question by findings of contrast when relative reinforcement rate has undergone no change. In cases such as signaling reinforcement, where contrast has (albeit unreliably) been observed, only response rate in the varied component undergoes any transformation.

The current work will focus on two approaches to the contrast problem, both of which are consistent with the generalized matching law. The differences between the two types of theories rest on their interpretation of the relationship concerning reinforcement interactions across time. It is universally accepted that reinforcement in a component does effect response rates in another component, the discord concerns how this effect is mediated. Thus in the multiple schedule the question is 'does reinforcement in a currently inactive component directly influence responding in the currently active component, or is that effect somehow mediated by other behaviours or reinforcers that the animal can reallocate between components'? Large bodies of empirical research are available to theorists providing a solid basis for explanatory theories. Unfortunately a

large part of this research seems contradictory and accounting for all the results seems an unattainable task from the outset.

There are two theories of direct interaction considered, these are Herrnstein's (1970) account of contrast using the relative law of effect, and Williams (1983, and Williams and Wixted, 1986) who expand on Herrnstein's equations using an account of reinforcement effects that includes inhibition as well as reinforcement. The basic premise of the account is that contrast is anticipatory in nature. The theories base their argument on reinforcement in one component having a direct influence on responding in another component despite the temporal separation. While contrast itself provides considerable first hand support for the theories there are some results (to be examined later) which pose major problems for these accounts. An alternative view of the interaction is that the effect is mediated via adjustments in other behaviours/reinforcers that occur in components. The two theories that endorse this view see contrast as a result of competition for the animal's behaviour within a single component between different response alternatives. Thus these theories are labeled competition theories of contrast and often are confused as the same theory. However Staddon's behavioural competition theory (1982) and McLean and White's reinforcer reallocation hypothesis (1983) do differ in important places to be outlined later.

THEORIES OF BEHAVIORAL CONTRAST

Theories of Direct Interaction

The Relative Law of Effect

In his 1970 review of the law of effect Herrnstein introduced a formula to account for both multiple and concurrent schedule interactions. Herrnstein saw the major difference between the two schedules being that because alternative reinforcement is temporally removed in the multiple schedule there should be less interaction between the components. According to Herrnstein behaviour in all schedules could be explained by Equation 2.

$$B_1 = \frac{kR_1}{R_1 + mR_2 + R_o} \qquad (2)$$

Again B_1 represents responding in Component 1, with R_1 being the reinforcement schedule for that behavior. R_2 represents reinforcement in the other component, which has a varying degree of influence on behavior in the present component according to a parameter (m) which can range from zero to one. R_O gives reinforcement for all behaviours other than the experimental response and k represents a constant quantity of behavior that is allocated within each component. Thus in a concurrent schedule where R_1 and R_2 are both available m is presumably 1 seeing as there is no way reinforcers can interact more than when they are available simultaneously. While reinforcer schedules alternate, as in multiple schedules, components are separated temporally and the amount

they interact presumably decreases, thus the value of this parameter decreases. The result is that not only does Herrnsteins equation predict absolute response rates as well as component interaction, but it also predicts contrast effects, and explains why contrast effects are smaller in multiple schedules as opposed to concurrent schedules. Note that provided m > 0 any decrease in R_2 will result in a corresponding increase in B_1.

By modifying Equation 2 Herrnstein could derive an equation for relative response rates for both components of the multiple or concurrent schedule. This was done using Equation 3.

$$\frac{B_1}{B_2} = \frac{\dfrac{kR_1}{R_1 + mR_2 + R_o}}{\dfrac{kR_2}{R_2 + mR_1 + R_o}} \qquad (3)$$

Equation 3 denotes the matching of relative response rates to relative reinforcement rates as being a function of the context of reinforcement in the two components. The equation predicts that the larger m is, or the higher the value of R_o is relative to R_1 and R_2, the closer the subject's approximation to matching will be. The equation predicts matching will only occur when interaction is 1, which is in a concurrent schedule. In all other instances undermatching will be prevalent, however the larger m is the closer the performance will get to matching (see Shimp and Wheatley, 1971 for validation of this prediction).

While Equations 2 and 3 do explain a large amount of the data and do specify the relationship between absolute response rates and rates of reinforcement, the equations (particularly Equation 2) make several incorrect predictions. This has been noted by a number of investigators thus only a brief account will be given here (see Edmon, 1978;

Williams, 1983; McLean & White, 1983; Williams & Wixted, 1986; for more in-depth exploration of these issues). Many of the problems with Equation 2 arise because any increase in the denominator either by increasing m, R_2, or R_o results in decreasing the response rate. Thus some incorrect predictions are made-for example, that responding in a multiple schedule VI 90-VI 90 will be slower than in a simple schedule VI 90 (see Spealman and Gollub, 1974). Likewise if other reinforers (R_o) are increased, Equation 2 predicts smaller contrast effects when the varied component reinforcement conditions are changed. Hinson and Staddon (1978) observed larger contrast effects when, by providing a running wheel for rats to use, they increased the amount of alternative reinforcement available in the component. One final criticism concerns the alternation of short components in a multiple schedule. Equation 2 predicts responding will decrease (because the components will interact more, thus m will increase), however Williams (1983) reviews studies showing that the behaviour in the richer component typically increases in frequency.

In that same article Williams also outlines a simple way of eliminating many of these problems. By changing the expression of the context of reinforcement to represent the average rate in the session (as in Equation 4) rather than the sum of the different rates, any increases in the denominator, such as increases in interaction, will no longer cause decreases in the behaviour output. Support for the equation does warrant further investigation using the logic of direct interaction, which is generally accepted as controlling schedule interaction.

$$B_1 = k \frac{R_1}{\frac{R_1 + mR_2}{1 + m} + R_0} \qquad (4)$$

This forms the foundation for the second direct interaction theory proposed by Williams and Wixted (1986).

Williams and Wixted's Theory of Direct Interaction

Catania (1973) argued that reinforcement not only increases the strength of the response on which it depends, but that it also inhibits all behaviour in the situation. This concept of inhibition by reinforcement can be extended to multiple schedules by assuming that the amount of inhibition is dependent on the amount of reinforcement. However Williams and Wixted (1986) argued that a simple average (as used in Equation 4) is not appropriate as different sources of reinforcement produce different degrees of interaction. They proposed Equation 5 to equate the response rate (B_n) in a component.

$$B_n = s\frac{R_n}{\frac{R_n + pR_{n-1} + fR_{n+1}}{1 + p + f} + C} \qquad (5)$$

R_n is the reinforcer rate in the current component, R_{n-1} is the reinforcer rate in the previous component and R_{n+1} is the reinforcer rate in the following component. The weights for the different sources of reinforcement (*p* and *f*) are relative to the rate of reinforcement in the prevailing component. S is a combination of the parameter k and C, and is expressed in units of responses/time. Finally *C* is a constant of inhibition expressed in units of reinforcers/time. According to Equation 5, contrast is a result of changes in the context of reinforcement, which in turn produces degrees of response inhibition. Thus although the reinforcement in Component one is the same in a multiple

VI 60 VI 60 and VI 60 EXT schedules, the context of reinforcement is different, and therefore predicted response rates are different. Inhibition varies as a function of the weighted average of reinforcement in the situation. The use of different weights is an attempt to account for findings to be discussed later, which suggest that the schedule that follows is a more potent source of behavioural contrast.

These same findings cause serious difficulty for any conception of matching as a general law of schedule interaction since they imply that matching generally cannot occur in a multiple schedule. This weighted average conception argues strongly against viewing matching of relative response rates to relative reinforcer rates as the limiting form of multiple schedule interactions. Thus it suggests a basic difference between multiple and concurrent schedules. Since most experiments utilize a two, rather than three, component multiple schedule Equation 5 had to be applied to the two component setting. In this setting the preceding and the following component will always be identical thus there is no need to consider the effects separately. By combining components the formula takes on the form of Equation 6, remembering that $p + f$ equals m.

$$B_n = s \frac{R_n}{\frac{R_n + mR_{n+1}}{1 + m} + C} \tag{6}$$

Williams and Wixted have received support for the anticipatory contrast equations by applying them to a large number of other studies done with two component multiple schedules and seeing how well they account for the findings. The quality of the fit

found has often been very high, for example often accounting for over ninety percent of the variance (see Williams and Wixted, 1986; 1994).

It should be noted here that while Equation 6 and its relative rate extensions does account well for a lot of findings Equation 1, the generalized matching law does provide a more accurate description under some circumstances (see Williams and Wixted, 1986). The original generalized matching law was discarded because it could not be applied to absolute response rates. These same figures, absolute response rates, appear to be causing major problems for both direct interaction theories of matching. It appears then that the real problem with quantifying behavioural contrast is equating what an animal will do in the present context. The competition theories present an alternative approach to modeling an organisms behaviour in a multiple schedule and it is based on a simple schedule equation.

Theories of Mediated Interaction

The basic notion of both theories is a distinction between two behavioural classes that an animal can engage in during a component. These are firstly the experimentally reinforced response (B_n) and the alternate being any other behaviour that the experimenter does not consider that they are reinforcing (B_o). The sum of these two behaviours constitutes total behaviour *(k)*, which is constant across components. Contrast in this view derives from competition between the two behaviours (or their reinforcers), thus behaviour can be understood in terms of the matching law, that is represented in Equation 7:

$$B_n = k \frac{R_n}{R_n + R_o} \qquad (7)$$

Note that the reinforcement in the other component can have an effect on behaviour in the present component but this effect is mediated by the reinforcement that is available in the current component.

Response competition effects have received wide attention in the treatment of simple and concurrent schedules (eg Rachlin, Kagel, & Battelio, 1980; Staddon 1979), however it has not received the same attention in multiple schedules. One assumes that this is because the different components are never available simultaneously therefore they cannot compete for the animal's time. However what can compete with the time the animal spends responding is the time the animal spends engaging in other activities. Herrntein's equation used the parameter to capture the asymptote of behaviour, that is the maximum amount of behavioural actions an organism can achieve given a certain time period. This of course is dependent on the physical characteristics of both the action and the organism, but both are constrained by the passage of time. The parameter Herrnstein used was k, which referred to the maximum behavioural output an animal is capable of within a component, and was measured in units of behavior. Therefore total behavioural output by the animal in the constant component is equal to behaviour output in the varied component. That is expressed in Equation 8.

$$Bpc + Boc = Bpv + Bov = k \qquad (8)$$

Where *P* is pecking and '*O*' is any behaviour other than pecking, c identifies the constant component and v the varied component, and as mentioned, *k* is the maximum behavioural output. The matching law dictates that *k* must be constant and independent of the different reinforcement dimensions

The fundamental question is do experimentally reinforced responses compete with non-experimentally reinforced behaviours. If they do it sets the stage for behavioural contrast in the two component procedure.

Behavioural Competition

When there is equal reinforcement in the components of a multiple schedule other behaviours that the animal can engage in will compete equally with the response required for reinforcement in each component. If the reinforcement in one of the components is lowered then the animal is likely to engage in other behaviours (B_o) during that component meaning that reinforcers for these behaviours (R_o) is likely to decrease. This decrease in R_o will result in less competition with the reinforcer in the unchanged component (R_n) thus resulting in an increase in responding. This is the fundamental principle behind Staddon's theory of contrast. The theory was based on a study by Hinson and Staddon (1978) in which contrast was produced in a number of rats. As noted earlier, the experiment included a running wheel to increase the value of R_o. The effect of the running wheel was examined with reference to the size of the contrast effect produced when one component was put in extinction. Figure 2 shows the resulting response rates for the different conditions.

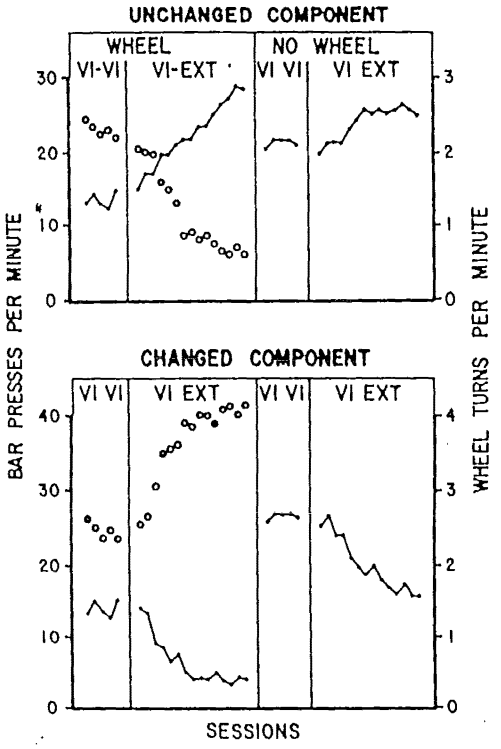

Figure 2: From Hinson and Staddon (1978) showing average daily rates of barpressing (solid lines) and wheel turning (open circles) for subjects in the unchanged (VI 60) component and the varied (VI 60 or EXT) component in each of the four conditions

Figure 2 shows that when the running wheel was present the component with the lower reinforcement had both more running by the rats and a more substantial decrease in responding. In the constant component the effect was the opposite, that is a strong contrast effect measured by an increase in responding, and decreased running on the wheel. This was measured against changes when the running wheel was locked so the animal could not engage in running. The results when the wheel was locked were that the effect was substantially smaller, that is contrast was weaker. The above results do suggest that competition may play a role in contrast. However an important question concerns how the competition is mediated. Staddon (1982) suggested that this occurs through transitory satiation and deprivation effects with respect to the activities generating R_o. Figure 3 shows an example of how this may work when a component with a high reinforcement rate alternates with one with a low reinforcement rate.

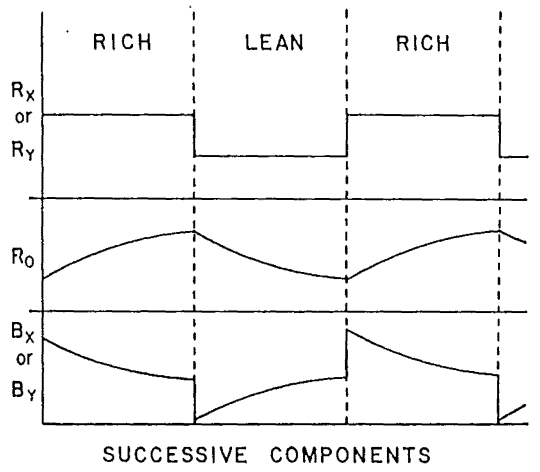

Figure 3: From Staddon (1982), shows hypothetical values of operant reinforcement (top) and reinforcement for other behaviours (middle) and the resulting operant behaviour (bottom). Time is represented along the horizontal axis.

As Figure 3 demonstrates, during the rich component the reinforcement causes the responding to occur at the expense of other behaviours since the animal is constrained by the time it has in the component to spend doing the different activities. Because other behaviour is neglected the reinforcers for this behaviour gradually builds up over time, just as the need to scratch an irritating itch increases when neglected. As a result the value of performing other behaviours is at a maximum at the beginning of a lean component thus here the animal is likely to engage in a number of other behaviours suppressing responding. Reinforcement for this other behaviour gradually diminishes through the lean component and when the animal enters the rich component R_o is at its lowest. The value of R_o then is a function of the amount of momentary satiation/deprivation, which in turn is a function of competition from the operant response.

The allocation of k in this account is sensitive to the relative reinforcer rate (R_1 versus R_o) obtained during the present component, but is insensitive to the reinforcer rate in the alternated component. That is, the components are independent. This is

supported by findings by McLean and White (1983) that indicated that changes in absolute response rates depend only on reinforcers obtained during their respective components. By using an experimental analog of R_o, food reinforcement for responding on a second key, they tested sensitivity and bias of responding in two component multiple schedule. The authors found that sensitivity increased as the analog R_o increased, and that bias was inversely related to the ratio of R_o in the two components. That is, as the difference between R_{01} and R_{02} increased, bias increasingly favoured the multiple schedule component with the lower analog R_0.

Reinforcer Reallocation Theory

While the above study by McLean and White did support 'behavioral' competition it was part of a paper that proposed another alternative competition theory with many surface similarities to Staddon's since both see the effect of R_2 as being somehow mediated by changes in the current (constant) component. However while Staddon's theory sees changes in competing *behaviour* as being the determinant of contrast, the reinforcer reallocation hypothesis sees the competing *reinforcement* as being the determinant. The theory assumes that the schedule maintaining responding behaviour in a component competes with a schedule of extraneous reinforcers. While these reinforcers are hypothetical, Herrnstein (1970), and Staddon (see above) have also argued for their existence. The idea behind then is both plausible and logical and as such their existence itself is not challenged in the literature, after all something must encourage the animal to engage in other activities. However unlike Herrnstein, the

reallocation view sees contrast as occurring due to the reallocation of extraneous reinforcers, which are available to the animal throughout the session and can be 'received' at any time.

The reasoning behind reinforcer reallocation is similar to Staddon's reasoning. Because in the constant component reinforcement from the experimenter is high the animal spends a large proportion of its time engaged in the behaviour required by the schedule. When the lean component is in effect the animal can receive 'other' reinforcers that have built up over time since the value of reinforcement provided by the experimenter is not as high. Thus the idea behind the theory is that these reinforcers firstly compete for the animals time, and they can move between components allowing the animal to collect them when experimenter reinforcement is lean. Catania (1963) demonstrated responding to be inversely related to the rate of concurrently available reinforcement. Therefore a reduction of R_o in the constant component should result in an increase in responding. Reallocation hypothesis like behaviour competition theory attributes the changes that are occurring in behaviour at the present to changes in the present context of responding. The theories differ though in the way they view this context as changing. Staddon sees it as a result of satiation or deprivation of behaviour, McLean, a result of the reallocation of extraneous reinforcers. The problem with the 'other reinforcer' concept is that the experimenter neither controls them, nor can he/she directly measure them although attempts have been made like that above to use an analog of R_o. In fact McLean has made a number of attempts at using these analog extra key reinforcers with these attempts resulting in considerable support for the reallocation hypothesis.

For example McLean (1992) arranged multiple-concurrent schedules for pigeons in a 2 key operant box. On one key a standard multiple schedule procedure was used with a constant reinforcer rate in one component and a varied reinforcer rate in the alternating component. A variety of schedules arranged reinforcers on the extra key. These all ran simultaneously through both components with a response producing a reinforcer if one of the 4 VI-100's had timed out or if the VR-425 had elapsed. A response counted toward the VR if it produced no reinforcer. McLean noted that like extraneous reinforcers these were delivered on a number of schedules, some interval based and some ratio based, and these reinforcers could be moved across components in the multiple schedule. In addition a constraint was imposed in some conditions that cancelled any reinforcers earned in a particular component if they were not collected by the end of that component. The effect of this constraint was that reallocation could not occur as reinforcers earned could not be received in other components. The results showed that firstly the procedure of changing the reinforcement conditions on the left key, of the multiple schedule, produced behavioural contrast. It was also found that in all subjects more of the extra key reinforcers, that could be reallocated, were obtained when the leaner multiple schedule component was running. It was also observed that when the constraint was imposed the contrast effect was reduced.

DIFFERENTIATING THE THEORIES

The debate between the two opposing conceptions of the effect of a reinforcer has been persevering for nearly two decades. While the theories both account for the

basic contrast effect, and many other observed findings, there are a number of areas where they differ. Given that each of the different accounts specifies the relationship between the reinforcer and the response in a different way, it would appear relatively easy to separate the accounts and determine which is the more accurate. While there are many areas in science where opposing theories reside together in an area of research, few oppose each other with the apparently distinct difference that is seen in this case. While it may appear then relatively easy to identify an area where different predictions are made, the theories have proved to be difficult things to pin down. The concept of other reinforcers and other behaviours, while making logical sense, provides a nightmare for the quantitative researcher. These concepts do not allow the degree of measurement that traditional response rate and reinforcement rate do. The following will be a review of the literature as it pertains to distinguishing between the theories.

There have been many reported observations of contrast in the literature as discussed earlier. In addition there are large amounts of literature that support the different theories, however much of it is broad enough in nature that it can not differentiate between theories, and as such supports them all. In terms of allowing comparisons of different theory adequacy, areas in which rival theories make clearly different predictions are the most interesting. That is areas where one theory predicts contrast while rival theories do not provides an excellent area of investigating theory adequacy. The present report focuses on three such areas of research, however, before embarking it should be noted that contrast has become such a complicated phenomenon that the overall effect appears to be the result of a number factors, each independent yet crucial to the overall effect.

The three crucial issues in the research are firstly determining the critical variable in contrast. That is the effect of varying the conditions of reinforcement so as to isolate response rate and reinforcer rate and see which has the larger effect on contrast. The second issue is the issue of successive independence. McLean (1991; 1995) presents evidence, to be discussed, suggesting that temporally distant components are independent, which naturally poses serious problems for theories of direct interaction. However the first issue discussed concerns the number of components in a multiple schedule, and the way response rate is recorded across those components.

Arranging and Recording Multiple Schedule Components

The Three Component Multiple Schedule

A possible theoretical problem with both competition theories occurs with predictions that would logically follow from the theories. In their present form both theories would predict that responding at any time should be more influenced by what occurred just before than by what is about to happen next. For example if an animal has just come out of a rich component where other behaviour has been neglected, responding will be low, as the competing R_0 will be high. In fact Staddon (1982) makes this precise prediction, which is that the preceding schedule will influence behaviour in the present component more than the schedule that will follow. It does not appear as logical that the animal will neglect B_0 now in anticipation of lean periods ahead.

A major premise in the weighted average model is that separate terms for the preceding and following component are required. Thus Williams and Wixted inhibition account uses a weighting approach for different sources of reinforcement where they

predict contrast to be influenced more by the schedule that follows, that is primarily anticipatory contrast. The anticipatory contrast approach was based on a study by Williams (1981) in which he examined the effects on contrast of varying the following or preceding component. The experiment consisted of a three component (A, B, and C) multiple schedule. By changing component B after baseline training, Williams could observe which of the other two components underwent the greater change. As the weighted average model suggests, responding in component A was the most affected. Williams also made the rather evident conclusion that the sum of the preceding and the following schedules comprised the contrast effect. Figure 4 shows the result of the second experiment.

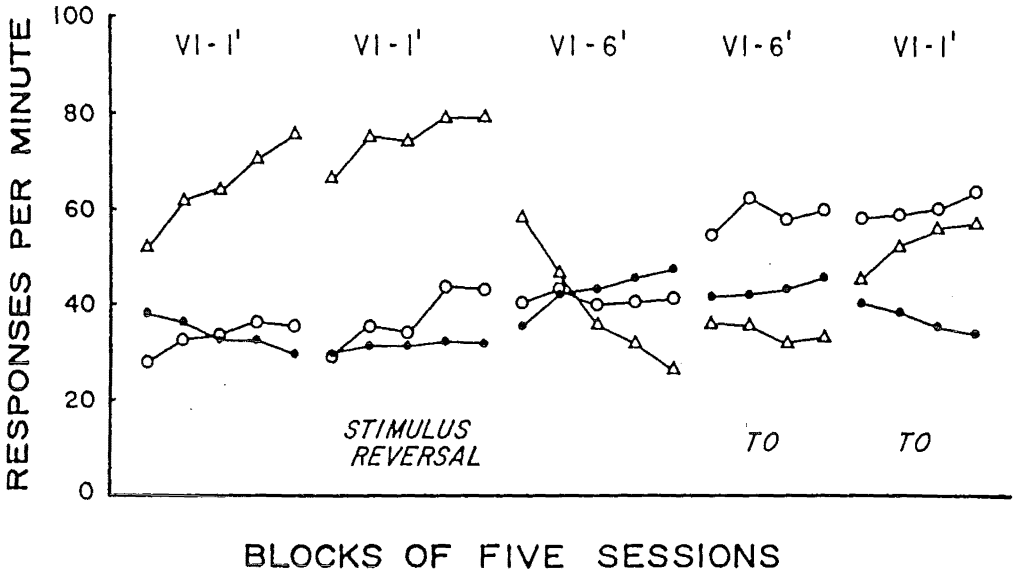

Figure 4: Results from Williams (1981) of a three component multiple schedule in which the reinforcement rate was varied during the middle component. The filled circles depict response rate in the first component, the triangles response rate in the middle component, and the unfilled circles depict response rate in the third component. Conditions in the first and third component were constant at VI 3 minutes. Conditions during the second component are displayed above each segment. The TO designation refers to time out being added after each complete cycle of the sequence.

Figure 4 shows responding in all three components when the varied (component B) changed from a VI 3 minutes to VI 60 or to VI 6 minutes. As can be seen the larger contrast effects are observed in Component A while responding was relatively stable in Component C. For example refer to the second and third, and the fourth and fifth segments where response rate changes little in the third component. The final two blocks show the results when a timeout (TO) was added after the completion of each (ABC) cycle. As displayed in Figure 4, an increase in responding was only observed in Component A (although response rate was higher in Component C it remained constant with changing conditions). Thus in the Williams (1981) paper the major effect on responding across the components, brought about by changing the reinforcement, was observed in the schedule that preceded the varied component, that is major support for the idea of anticipatory contrast.

In 1986 Williams and Wixted set about providing a replication of the above study which is worthwhile considering the counter intuitive nature of the results. They again used the three component procedure this time holding one component constant while the conditions around it were interchanged between successive conditions. Response rate in the constant component can then be compared with respect to whether it was higher when the reinforcement in the preceding or following component was lower. For three of the four subjects, the experimentally determined weights for the following component schedule were considerably larger than those for the preceding schedule. For the last subject the effects of the two schedules in contributing to contrast were comparable. The findings then provided a nice replication of the 1981 study and seemingly provide clear evidence against the competition theories.

The results are problematic for the competition theorists as a central idea of both behavior competition and reinforcer reallocation is that other behaviours/reinforcers are being transferred into the alternate component meaning less competition with the response or less satiation. The notion works better if it is the schedule that occurred prior to the current schedule being the more potent source of contrast as discussed. While it is not illogical for an animal to anticipate lean (or rich) times ahead, experimentally speaking, and so deprive behaviour now, this notion of anticipation would make both reinforcer reallocation and behavioural competition redundant since anticipation would be the primary mechanism involved in contrast. Williams and Wixted have not elaborated as to why this result should occur, their weighted model requires no explanation, the terms are there to account for this finding. The result being that anticipatory contrast does provides a problem for the two competition theories.

Local Contrast Studies

Fortunately for the competition theorists local contrast studies provide some respite from the problem of 'anticipation'. Comparisons of behavioural contrast are typically made in terms of overall rate of responding by session time. However there is a large body of literature suggesting that responding within a multiple schedule component is not constant. If the following schedule is the more potent source of behavioural contrast then local contrast studies should show a gradual increase in responding across an individual component if the following component is the leaner of the two. The reason is that, as it is the anticipation of the next component that is causing the effect, as the component draws closer the effect should get greater. There is however

Local Contrast data that shows the opposite effect, which is response rate changes are the most dramatic at the beginning of a component.

Defining local contrast provides the same difficulties as defining contrast itself, and as with contrast, it must be defined relative to the adjacent schedule. Schwartz and Gamzu (1977) define local positive contrast as "*an initial elevation followed by a lower constant response rate in a given component if the overall response rate in an immediately prior component is lower than the overall response rate in the given component*" (p.77). Local contrast was referred to as transient contrast in earlier studies however, researchers went away from using this term leaving it to define the controversial effect of the disappearance of contrast after repeated exposure.

Nevin and Shettleworth (1966) studied a multiple schedule with three-minute component durations, recording response rates every thirty seconds. They found that if responding was lower during the preceding stimulus (that is for an animal entering a richer component) the response rate was significantly higher in the first 30 second interval, then decreased to a constant rate following this. This effect was mirrored when the animal entered the leaner component, that is low responding then leveling off at a slightly higher response rate. In the second part of the experiment either EXT or VI 120 in red preceded VI 60 reinforcers. Again local contrast was clearly evident as if the previous component was EXT response rate started higher, if it was VI 120 response rate was higher but not as high as in the EXT case. The level of responding late in the constant component appeared about the same in both conditions. Nevin and Shettleworth interpreted the results as the consequence of short term after effects of excitation or inhibition, depending on the frequency of reinforcement in the preceding

component. They did not think that sustained contrast effects could be attributed solely to these local effects and looked for relative reinforcement to explain the difference.

Thus there is some suggestion that local contrast and contrast may be due to different processes. This is highlighted in a study by Freeman (1971) using rats in a mult VI 2min EXT schedule, in which she failed to find overall positive contrast however did observe signs of local contrast. In fact the overall result was often negative induction. While the results do suggest Contrast in rats is not as reliable since it failed to occur, the observation of local contrast does suggest that this may be controlled by a different mechanism. The issue then is not whether local contrast contributes to overall contrast since clearly it does, the issue is whether the relationship is necessary, Freemans study suggests that it is not (see also Boneau & Axelrod, 1962; Malone, 1976; Williams, 1981).

There is then three component procedures which suggest that satiation or reallocation must occur in anticipation of future occurrences, not as a result of previous conditions, a result which lacks some plausibility from a competition point of view and which threatens the requirement of 'competition' in theory. However there are local contrast studies suggesting response changes occur most at the start of a component, suggesting response rate is not anticipatory, supporting the notion of competition. Williams (1981) has dismissed these later findings to a large degree claiming they account for only a small portion of the total contrast effect. The three component procedure and the local contrast results contradict each other with each supporting the aspects of a different theoretical approach to schedule interaction. The prospect that different contrast effects may be caused by different things is unfortunate but may be the

conclusion that this line of research is heading towards. At any rate this is one area of the contrast literature that is still very confused. Gaining unequivocal support for either view is thus impossible at this stage.

Interacting or Independent Components?

The issue of Successive Independence

Like the theory proposed by Herrnstein, Williams and company assume that, despite the temporal constraints imposed on responding by a multiple schedule, the components still interact, that is successive interaction. The main evidence supporting this is positive contrast itself, whereby a decrease in R_2 correlates with an increase in P_1. This is the fundamental point at which the theories part. The competition theorists claim that this correlation is not a result of direct reinforcement interaction but rather a result of a reallocation in the reinforcer ratio (R_1/R_{01}). In this view the change in R_2 has its effect on P_1 via its effects on R_{01}.

McLean (1991) studied local contrast in multiple-concurrent schedules in which Component A was held constant (left key VI 1.5min, right key VI 3min) while the left key in Component B was varied over 5 conditions from VI 0.75min to VI 6min. The right key in Component B was also held constant at VI 3min. The response rate was measured 4 times in each component allowing both local response rate and overall response rate to be studied for each component. Williams's (and Wixteds) theory of direct interaction would predict that a change in the reinforcer ratio in the varied component would produce an inverse change in response ratio in the constant

component. That is, as the ratio of left to right key reinforcers increases in the varied component the ratio of left to right key responses will decrease in the constant component. Because competition theories of Staddon and McLean see contrast as the result of mediated interaction, both theories predict independence of the components thus no change in the constant component response ratios. Both theories would predict a change in responding within the varied component.

Figure 5 shows behaviour allocation in the varied component and in the constant component as a function of the reinforcer ratio in the varied component.

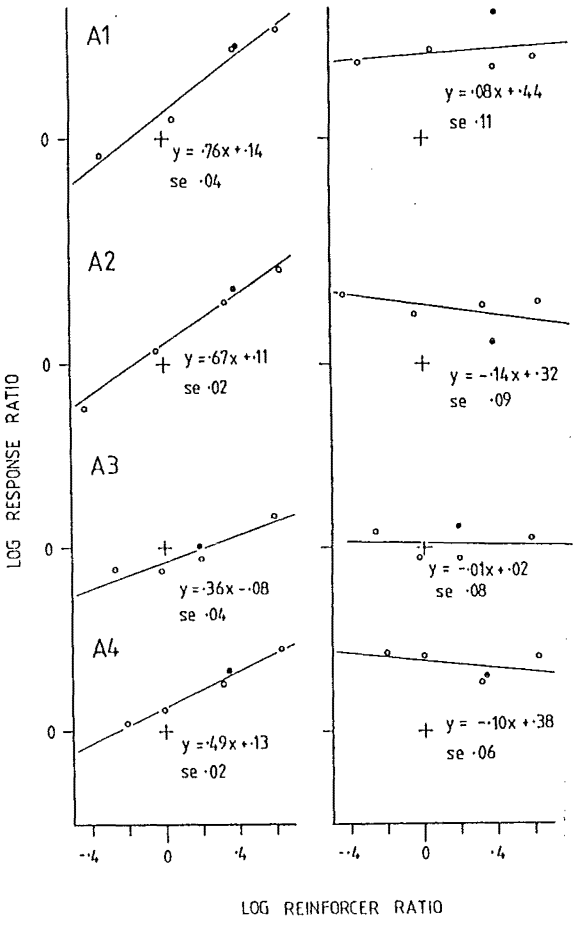

Figure 5: From McLean, 1991. Log response ratios (left/right) during Components 1 and 2 are plotted as a function of log reinforcer ratios during Component 2. Left side gives performance in the varied component. The right side gives the constant component. Least squares regression lines are shown for each bird. Filled circles give performance in Condition 1.

Figure 5 shows the constant component response ratios on the right hand side. Unlike the varied component (left side of figure 5) in which the increasing regression line slope (ranging from 0.36 to 0.76) indicates interaction, the slope of the regression lines is not significantly greater than zero (0.08 to -0.14). This result suggests successive independence, as response ratios in the constant component are not significantly different following changes in the varied component's reinforcer ratio. As a result the experiment clearly fails to support any theory of direct interaction between components. Interestingly, while there is no support for direct interaction provided by the overall response rates, the local contrast studies, which as reported earlier by Williams as not applying to anticipatory contrast, do provide support for direct interaction. Figure 6 shows the local contrast results from the McLean study.

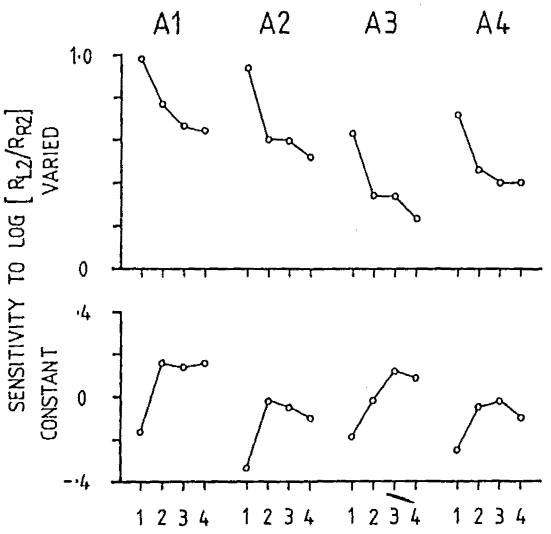

Figure 6: From McLean, 1991. Slopes of regression lines fitted to Component 2 log response ratios (upper panel), and Component 1 log response ratios (lower panel) versus changes in Component 2 log reinforcer rates. Slopes plotted over the four subintervals of the component.

The sub-interval data (Figure 6) show that for the first sub interval (or first quarter of the component) there is some evidence of successive dependence with the inverse relation evident in the lower (constant component) panel. That is, the constant component initially was sensitive to the varied component reinforcer ratio changes as evident by the initial slope of the regression lines. This effect quickly disappears as the subjects regression lines revert back to horizontal, or in some cases swing back to an opposite effect. This suggests that the schedules may interact at the very beginning of each component. Thus Williams, who earlier has demonstrated that local contrast does not support his anticipatory model but rather claims direct interaction is left with support for direct interaction by local contrast studies, not by overall response rates. That is the findings suggest that only local contrast represents direct sensitivity of behaviour in one component to reinforcement conditions in another component, overall contrast is better explained by reinforcer reallocation (McLean, 1995). As a result of this problem, the competition theories appear to receive more support from the study than their counterparts. However accounting for contrast by the reallocation of R_0 or the satiation of B_0 is still yet to be supported directly. Reinforcer reallocation theory posits that unlike food reinforcement provided by the experimenter, extraneous reinforcers can alternate between components as was demonstrated in the study by McLean and White (1983) which demonstrated reallocation of extra reinforcers [these used as an analog to R_0]. The competition theorists as a result claim successive independence between components.

White, Aslop, and McLean (1992) varied multiple concurrent VI schedules over 16 conditions searching for evidence of behavioural contrast and successive

independence. The experiment achieved its major aims. By varying one schedule while holding both its concurrent partner, and the alternating schedules constant, behavioural contrast was observed. Successive independence between components of multiple concurrent schedules were also observed in both 24 hour closed economy and 1 hour open economy sessions. The study also showed that contrast was not influential over successive independence. These results support both Staddon (1982) and McLean and White's (1983) interpretation that contrast in multiple schedules is not a direct result of interaction between temporally removed components. They are consistent with the notion that it is the availability of the extraneous reinforcers that are mediating the change.

The results are inconsistent with the major assumptions underlying the interaction theories of Herrnstein and Williams, that is it does not appear to be direct interaction of reinforcers that is influencing the changing response rate. Before examining the next topic of contention, that being the status of relative response rates it is important to look back on what has occurred. The theories are divided by the way they view components in a schedule as interacting. The fundamental difference is that Herrnstein and Williams (and Wixted) argue that components in a schedule (either concurrent or multiple) interact directly, in spite of temporal separation in the multiple schedule, therefore reinforcement in one schedule has a direct effect on behaviour in another schedule. The competition theories of Staddon and McLean (and White) see the effect as mediated by either other behaviours or other reinforcers.

The studies McLean has conducted support the notion of successive independence, that is responding in temporally distinct components is independent of

reinforcers in other components. McLean has also demonstrated that an animal can reallocate reinforcers, in the form of an extra key, to times of lean main key reinforcement. Williams though has shown that contrast is more a function of conditions in the following schedule than conditions in the preceding schedule. This goes against Staddon's initial view of satiation and against basic logic of how reallocation would work. The third and most contentious issue is the status of relative response rates in the varied component to the overall contrast phenomenon.

The Status of Relative Response Rates

Is Responding a Critical Variable

As discussed the problem with describing contrast is that the controlling force behind the phenomenon has yet to be fully discovered. While the reinforcement in Component 2 (the varied component) is still primarily identified as the determinant, how it affects responding is still a contentious issue. The problem is that in traditional demonstrations of contrast explanation is confounded by the way response rate and reinforcer rate change together. When extinction is introduced into a situation two things happen. The first is that reinforcement is removed from the component and the second, as a result of this removal, is that the previous contingency between responding and reinforcement is removed which in effect reduces response rates to virtually zero. There is still no satisfactory account of the status of each of these phenomenon in the production of contrast. By designing an experiment in which one is held constant while

the other varies, in either direction, one could assess the contrast effect and come closer to identifying the true cause.

Because the reinforcement is contingent on responding, and without reinforcement responding does not occur, it does not seem possible to design an experiment in which response rates remain constant while reinforcement rates decrease. However there has been a few attempts at doing just this in the literature. If the resulting manipulation produces contrast despite any decrease in responding in the varied component then this would seemingly provide strong evidence in favor of the reinforcement in the components interacting directly.

Halliday and Boakes (1974) designed an experiment to test whether contrast could be produced without a decrease in responding in the varied component. The procedure involved training the animal on a mult VI VT schedule. A Variable Time (VT) contingency makes reinforcement contingent on a certain amount of time having expired, in much the same way as a VI does. The difference is that in the VT schedule no response reinforcer contingency exists. Thus once the schedule has set the reinforcer up it is delivered automatically. The VT procedure produces a very low response rate. Thus despite reinforcement being equated in either component in the Halliday and Boakes procedure, responding in Component 1 was far greater. Once response rates stabilized in the constant component the VT component was changed to EXT. Given that the response rate was all ready at a marginal level it could not decrease any more thus only the reinforcement rate changed.

A similar experiment had been attempted earlier by Wilkie (1972) using primarily rats, although one pigeon was also used. Wilkie exposed his subjects to a mult

VI VI for baseline sessions. This was subsequently altered to a mult VI VT. Wilkie failed to observe any evidence of an increase in responding in the VI component, despite the decreased response rate in Component 2. In fact if there was any trend in the data it was towards overall induction. Following this the conditions were again changed, this time to multiple VI-EXT. Here behavioral contrast was observed in all cases. The increased Component 1 responding occurred despite responding in the extinction component remaining at the same level as responding in the earlier VT component. There was only one case where the EXT component produced lower responding than the VT component. Finally the conditions were changed back from multiple VI EXT to multiple VI VT resulting in the elimination of behavioral contrast in the VI component. The results indicate that the decrease in responding in the varied component is not a sufficient condition for the occurrence of contrast.

Similarly, Halliday and Boakes found that the transition from multiple VI VT to multiple VI EXT produced a considerable increase in Component 1 responding. Consistent with Wilkie contrast occurred despite Component 2 responding being at EXT levels before the EXT component was introduced. Contrast without a change in component 2 responding does not provide much support for theories that emphasis what the animal is doing in the varied component.

This line of research has held response rates constant, usually at virtually zero, while reinforcer rate is manipulated. The more common manipulation in this line of research is to hold the relative reinforcement rate in the two components constant while either weakening the response reinforcer contingency, or placing a restriction on responding, so as to decrease the animals response rate in one component. The result of

this manipulation is that, again, only one of the two possible variables, that being response rate, has undergone any change. What the subsequent effect is on the constant component will provide further evidence as to the variable of fundamental importance in contrast. Here the VT procedure is used again, however before the change of interest was from VT to EXT causing reinforcer rate to change while response rate remains the same. The change of interest in these later studies is from VI to VT, where reinforcer rate remains constant while response rate changes.

Other procedures allow the experimenter the same control as this allowing a clear opportunity to resolve this debate, as on the surface both theories make different and opposite predictions. The first is to no longer make the reinforcement contingent on responding. As discussed earlier a Variable Time (VT) contingency removes the need for the animal to respond and, as such, results in a rapid decrease in responding. A second procedure is to provide a signal for an animal in a VI that is presented when the schedule has timed out, thus the animal need respond only once to receive the reinforcer. While this does not remove the contingency between responding and reinforcement, since the animal has to respond once upon arrival of the signal to receive the reinforcement, it does remove the contingency when the signal is absent. Another is to use a procedure known as a Differential Reinforcement of Other behavior (DRO) where the animal is delivered reinforcers as in the VT schedule provided the animal has made no response over the entire interval. If the animal respond the timer is reset which, not surprisingly, results in a more rapid decrease in response rates than a VT schedule alone. Alternatively the availability of reinforcement can be dependent on the animal having certain inter response times, that is a certain time period must pass between one response

and the next for the reinforcer to be delivered. This procedure is known as a Differential reinforcement of a low rate of responding (or DRL) and is the first procedure considered below.

This is an important issue in evaluating between the two groups of theories. If the affect of the reinforcement is direct, as Herrnstein and Williams claim, there should be no contrast effect when the reinforcement rate in the varied component has undergone no change. The competition theories, on the other hand hold that what an animal is doing in a component determines the level of satiation or the amount of reallocation the animal can achieve. If the animal is responding at the low levels seen in extinction, then the direct interaction theorists argue that the animal can be engaging in these other behaviors that compete with the reinforced response in the constant component. Thus they argue that if response rate declines in the varied component contrast may be observed in the constant component regardless of levels or patterns of reinforcement.

Differential reinforcement of a low rate of responding

The time period (t) that must elapse between responses in the DRL for a response to be reinforced is determined by the experimenter and can be adjusted easily. Once t seconds has elapsed without responding the computer sets up a reinforcer, which the next response will produce. If the response occurs before t seconds has passed the time is abandoned and this latest response becomes the new time criterion from which t seconds begins. Thus the DRL component favors pauses between responses, thereby lowering the amount of responding over the session. The experimenter can also have some control over how much reinforcement the animal will get by modifying t.

Terrace (1968) conducted a number of contrast experiments, included one in which a DRL contingency was used in one component. The aim of the experiment was to determine whether contrast was a result of a reduction in the rate of responding associated with a particular discriminative stimulus, or a reduction in the rate of reinforcement associated with that stimulus. Baseline consisted of a period in which reinforcement was constant (VI) before the test phase was introduced. A DRL contingency was then introduced in the varied component. The value of the DRL was modified daily in an attempt to keep the number of reinforcers in the varied component at least as high as in the constant component; these values ranged from 6 to 8 seconds. The components alternated with 1-minute durations in each. The performance of three of the six subjects showed clear contrast as responding in the constant component increased when the response rates in the varied component decreased. In no session did the proportion of reinforcers in the varied component fall below 46%, in most cases reinforcement was more than 50% of the total reinforcement. Of the other three subjects

one seemed insensitive to the design as varied component responding never decreased. One showed induction as constant component responding decreased, and the other demonstrated neither an induction nor a contrast effect.

Following this Weisman (1969) conducted an experiment with a similar design, that is an adjusted DRL component was added after mult VI VI training. To maintain equality with amounts of reinforcement the minimum duration of the DRL was adjusted during each session of discrimination training. The adjustment appeared successful as once again reinforcement rates were near equal. All four animals demonstrated a Contrast effect, that is increased responding in the constant component after the changes in the varied component. It would appear then that the contrast effect is not dependent on any reduction in the rate of reinforcement in the varied component. The results point to the decrease in the response rates in the varied component as the determinant in Behavioural Contrast.

Differential reinforcement of other behaviours

The conclusion that Weisman came to following the previous experiment was further supported in a following study he conducted a year later (1969). In this study Weisman introduced a schedule that differentially reinforcers other behaviours (DRO). Here responding in the presence of the stimuli is not only not necessary, but is actually detrimental to the amount of reinforcement that the animal can get in the session. The DRO schedule is also time based with *t* again set by the experimenter. The period begins elapsing at the start of the session, at the delivery of the last reinforcer, or at the last response. The reinforcer is delivered at the completion of the period unless the

animal has responded, in which case a new time period begins. Two important qualities of this schedule are that firstly a DRO schedule produces a more rapid decline in responding than a DRL schedule. This is not surprising given that the DRL schedule still requires responding, and reinforcement in the DRO schedule will never get any closer to the response than *t* seconds. Secondly by adjusting the value of *t* the experimenter can once again influence how many reinforcers the animal is likely to get in the session. Again Weisman was looking for a Contrast effect when equal reinforcement was available in the two components.

Earlier Reynolds (1961a) had used a DRO schedule in his initial demonstration of Contrast. He alternated a VI with EXT and with a DRO (*t* was either 50, 55, or 75 seconds) for four pigeons. He concluded that 'generally' responses in the unchanged VI increased when the varied component was put in EXT, but did not increase when the varied component was changed to DRO. Weisman's study differed from Reynolds's in that he adjusted the DRO time value in the blackouts preceding each DRO trial, thus equal reinforcement was obtained between the components in the multiple schedule. Like the results Weisman achieved with the DRL schedules, all four pigeons showed marked increases in response rate in the constant component associated with a reduction in varied component responding.

The three studies provide support for competition claims since contrast has been produced in these instances despite constant reinforcer ratios across conditions. This provides evidence suggesting a strong role in contrast for what the animal is, or is not, engaging in. However there is also a wealth of contradictory evidence to this claim from later research, more methodologically sound that have found opposite results.

Bloomfield (1967) arranged a multiple schedule with a constant VI 1min schedule in one component and, after training on an equal VI, added either FR or DRL schedules in a second component. He found that equivalent changes in reinforcement rate in the varied component had similar effects on response rate in constant component. This is despite the FR schedule leading to higher responding in the varied component and the DRL leading to lower responding in the varied component. Similarly Nevin (1968) ran a multiple schedule experiment where, again after training, the second component was now associated with a DRO or EXT schedule. Although both schedules eliminated responding to a similar degree in the varied component only the EXT produced reliable Contrast effects in the constant component, with a varied component in DRO producing some evidence of induction in the constant component. These results led Nevin to suggest that eliminating key peck behavior in the presence of the varied component stimuli is not, by itself, a sufficient condition for Contrast.

There appears then to be a major discrepancy in the results reported with the intermittent reinforcement. Boakes, Halliday, And Mole (1976) conducted a series of experiments in an attempt to clear up the inconsistency. They questioned how successful either Terrace (1968) or Weisman (1969, 1970) had been at equating the levels of reinforcement across the entire session. They also criticized the two earlier studies as neither had returned the conditions to baseline following the test phase to allow for a better measure of the Contrast effects. While few studies do use this procedure it is a valuable practice to ensure the results are not just the artifact of fluctuating baseline levels. The Boakes et.al procedure involved yoking the subjects to a control for the test phase based on similar baseline performance. In the yoking

procedure the test animal is paired with a control animal operating in a standard mult VI VI condition. When this 'leader' animal obtains a reinforcer, the 'follower' animal (the test animal) has a reinforcer set up (or delivered depending on the condition). In that way the animal's level of reinforcement throughout the component can remain constant. In addition the animals were returned to baseline conditions following each condition to counter the problem of a possible rising baseline. In this regard, the methodology of the experiment was very sound.

The Boakes et al procedure was similar to both Terrace and Weisman's earlier attempts. However time was adjusted at the end of each component to attempt to ensure that local reinforcement rates were equated. They argued that earlier attempts had not achieved this. The procedure was effective as reinforcement densities were close to equal in the two components. As well as this, the DRL yoked partners had close interreinforcer intervals. Thus the reinforcement was reasonably well spaced out across the session. The baseline response rates determined the matching of animals. The DRL schedule was effective in decreasing response rates in the varied component relative to both baseline, and component two response rates of its yoked partner, in four of the six birds. Despite this decrease though no animals showed an increase in their constant component response rates, that is no Contrast. Finally the reinstatement of baseline conditions increased Component 2 responding, with Component 1 responding remaining the same. The results seem to favor the earlier interpretation of no contrast effects, that is the procedure has resulted in significant change in the varied component in the form of a decrease in response rate, however no change in responding has been observed in the constant component. The Boakes et al experiment then went on to test whether the

animals in the experiment was sensitive to the manipulation by using EXT rather than DRL, and found the traditional results, namely a strong Contrast effect. Thus the animals in the experiment were sensitive to the manipulation in that they demonstrated contrast when traditionally contrast-producing procedures were invoked.

This experiment also highlighted the important issue of the dangers of a rising baseline. Before the test phase baseline appears relatively stable. However in test phase the control subjects, who had experienced no change in conditions, demonstrated a rise in what would be the constant components responding. This rise in responding may well have been construed as a Contrast effect if the conditions in the second component had been altered in some way, for example the introduction of a DRL schedule.

In the second phase of the experiment Component 2 was changed to a DRO schedule while again using the same yoking and return to baseline procedures as previously used. Again *t* was adjusted to ensure comparable reinforcement in the two components. The success of this was not as striking as in the previous experiment with some subjects receiving considerably more reinforcement in the varied component. The results they received were far less conclusive than the results from the first part of the experiment. Only one bird showed signs of Contrast with its yoked partner not demonstrating an increase in constant component responding. While only one Contrast case out of six animals may seem to suggest Contrast is not occurring, only two of the animals demonstrated no Contrast. Of the others two of them showed signs of induction while the other seemed insensitive to the whole procedure. The EXT condition that followed also failed to produce Contrast in two of the animals. Boakes, Halliday, and Mole concluded that there was no evidence from their study to suggest that response

reduction in one component of a multiple schedule will lead to a response increase in the other components when rates of reinforcement remain equal. They claimed that the increases that Terrace (1968) and Weisman (1969, 1970) reported were due to either an uneven distribution of reinforcement or to a naturally rising baseline.

This line of research has again uncovered a number of conflicting results, thus neither theory can claim unequivocal support from this area. While the latter studies by Boakes et al. do seem methodologically sound the study has not been replicated in its initial form It would, therefore, be premature to dismiss entirely the results of previous researchers, who clearly observed contrast effects. It should be noted that while the DRL and DRO schedules do lead to a decrease in responding in the varied component they does so by imposing a new response contingency. Here responding is basically correlated negatively with reinforcement since, given a minimal rate of responding on a DRL, more responding will be associated with less reinforcement.

Signaled Reinforcement

Like the DRL schedule, signaled reinforcement decreases response rate while still maintaining some control over the delivery of reinforcement. Signaled reinforcement is an addition to a simple VI schedule, thus any responding before the reinforcer is 'set up' by the computer does not influence the delivery of reinforcement. When the computer sets up a reinforcer a stimulus is presented to the animal signaling its availability. Because of the consistent pairing of the signal and reinforcement, and the absence of reinforcement without the signal, responding in the absence of the signal

decreases. Importantly, although the response rate may decrease reinforcement rate can remain constant as the animal is still receiving the reinforcement.

Some reviewers (see Marcucella, 1976) have argued that the signaled reinforcement procedure, when consistently paired with every reinforcer, becomes a three component multiple schedule. The varied component is now comprised of the original stimulus which, because it is never paired with reinforcement, can be viewed as EXT. The new signal that is added only occurs when a reinforcer is available and only requires one response to deliver it, thus can be viewed as a fixed ratio 1. Therefore the three stimuli signal different reinforcement conditions and operate at different times. The components though will not be available for the same periods of time, nor will they change over at regular intervals.

Marcucella (1976) conducted an experiment using a multiple schedule looking at the effects of changing a VI-VI to a VI-sigVI (or VI-sigVT) schedule. If the availability of the reinforcer was always signaled by the stimulus (sometimes the stimulus was only present 50% of the time) positive contrast was observed in the constant component, that is an increase in responding following the decrease in responding in the varied component. This contrast effect was not observed when the signal was only 50% accurate; in fact negative induction seemed to be the most common outcome in this case. This study had been preceded by earlier studies that had found similar results while also employing the signaled reinforcement approach (see Brownstein and Hughes 1970, Brownstein and Newsom 1970, Wilkie 1973). Like the occurrence of contrast with DRL/DRO schedules, contrast in this case provides evidence against relative reinforcement being the controlling variable since again this had not changed.

Marcucella (1976) argued that discriminated periods of extinction resulted in the development of autoshaped pecking to the positive discriminative stimuli, that is the constant component stimulus, thus resulting in a contrast effect.

Williams (1980) conducted another signaled reinforcement study however this time he varied component duration. The specific problem that Williams was addressing was the effect of local Contrast, which it had been suggested were controlled by different variables than the effects on average rate throughout the component (Malone 1976, Schwartz 1978). There was also previous research that had shown that shorter component duration's promote greater interaction between components (Shimp and Wheatley 1971, Todorov 1972), this in turn should (according to direct interaction rationale), produce greater contrast effects. Williams varied component durations to either 15, 60, or 300 seconds. His results supported the conclusion that relative rate of reinforcement was the controlling variable for interactions. There was no change in constant component responding observed when the varied component was in the signaled condition that was different to changes when the varied component was also VI.

Figure 7 shows the results that Williams received. The figure clearly demonstrates that in his subjects contrast is greater with shorter components, and EXT produces contrast effects while signaling the reinforcement does not. The findings provided good support for the direct interaction theories of contrast.

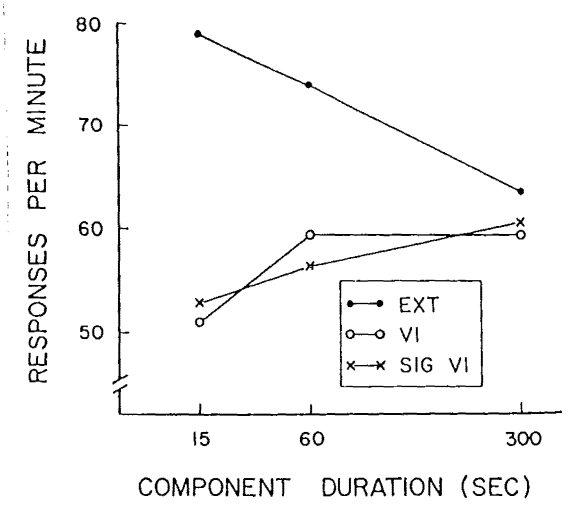

Figure 7: Figure from Williams, 1980. Results of a two-component schedule showing the means of four subjects for responding during the unchanged VI 3 minute component when conditions in the varied component were either extinction, VI 1 minute, or signaled VI 1 minute. All conditions were run under three different component durations.

Following this Gutman and Fenner (1982) conducted three Contrast experiments using Mult VI VI as the baseline and varying the second component to either EXT or signaled VI. The study was quite extensive using 12 pigeons as subjects. Eight of the pigeons clearly showed no signs of Contrast when the varied component was the signaled VI. The first part of the study had conditions that were virtually identical to Wilkie's (1973) study that had demonstrated Contrast. The reason for the striking difference in the results is unclear, given that both experiments used VI 1min components and had 3-min component duration's, the results are rather baffling. In the second experiment Gutman and Fenner divided the birds into three groups. Two of the groups were exposed to the signaled VI again however this time the groups had different signals. The third group was run with the traditional EXT condition. Of the first two groups only two animals showed clear increases in constant component responding, which in both cases was not followed by a return to baseline levels in the final condition.

This is in total contrast to the EXT group where all the animals showed clear, immediate increases in responding and all but one showed clear response decreases when baseline was reintroduced.

There seems to be good support then for the claim that the signaled reinforcement procedure does not produce contrast in the standard multiple schedule experiment. This is despite the clear effect that signaling reinforcement has on response rate in the signaled component, that is a dramatic and immediate decrease in responding.

Variable time Schedules

The variable time (VT) schedule has the advantage over the other conditions discussed in that, like extinction, the VT schedule eliminates any contingency between responding and reinforcement. As discussed the VT schedule does this by making reinforcement independent of responding. Food (the reinforcer) is presented after an interval of *t* seconds regardless of what the animal is doing or whether it is responding. When an animal is exposed to a VT schedule, after training on a VI, responding traditionally declines fairly rapidly before leveling off at a level just higher than the response rate observed in EXT (Skinner 1938, Halliday and Boakes 1974). Since there is no demands made on the animal's time by the VT contingency, the animal is free to engage in other behaviours. However the reinforcer is only available to the animal for a limited period of time, thus the closer the animal is to the hopper that dispenses the food the less reinforcer availability time it will waste moving to the hopper.

There is primarily one study at the center of all the VT discussion that there has been in the contrast literature. This study has been at the center of a longstanding

debate involving considerable interpretations of the results, with some commentators claiming that the findings dismiss the competition theories. Halliday and Boakes (1971) studied VT using the same Contrast design as the previous studies, namely mult VI VI, mult VI VT, and mult VI EXT. They selected eight subjects on the basis of good reductions in responding in trial conditions, and subjected them to baseline mult VI 60 VI 60 (components of 90-second duration) for a minimum of 16 sessions. One of the subjects was discontinued after 27 sessions as it still showed considerable variability. In the test phase for three subjects the presentation of a 50° rectangle signaled extinction (this mult VI 60 EXT). For the other four subjects the same stimuli signaled VT 60 (thus mult VI 60 VT 60). For each subject responding to the varied component decreased steadily when the test condition was added, although this decrease was more rapid in the subjects exposed to extinction. For the VT group responding to the constant component initially decreased slightly, returning to baseline levels for two of the four birds. There was no evidence of positive contrast. For the three EXT subjects, clear contrast was demonstrated when the test conditions were added, however there was no subsequent return to baseline so it is unclear how much of the change was a result of the changes in the varied component.

The important result of the experiment was that a decrease in responding in the varied component, resulting from the introduction of a VT contingency, did not result in an increase in responding in the constant component. The result suggests that decreasing the response rate is not a sufficient condition to produce contrast, and while it still may be a necessary condition, the experiment seems to provide damning evidence against the competition theories.

Both Halliday and Boakes (1972), and Weisman and Ramsden (1973), have shown conclusively that a decrease in responding is not a sufficient condition for behavioral contrast. Here when varied component response rate decreases due to the introduction of VT in Component 2, Component 1 response rates remain constant or may even decrease slightly. This is known as induction and is the reverse of contrast, namely responding in the constant component moves in the same direction as response rates in the varied component. The absence of an increase is different from similar effects where varied component response rate falls away due to extinction. Some reviewers (for example Terrace, 1972; Halliday and Boakes, 1972) view the constant component increase as dependent on the decreasing response rate in the varied component. Although the decrease alone may not be sufficient to produce the phenomenon.

This research then has uncovered three experimental designs that reduce the animal's response rate in the varied component but leave the amount of reinforcement they receive in that component at a rate similar to that they received before the condition change. These procedures; DRL, DRO, signaled VI, and VT, however seem to show with some consistency that the decrease in responding in the varied component, that these designs consistently produce, does not result in an increase in responding in the alternating constant component. This appears to provide damning evidence against competition theories since, due to the response constraints being removed, the animal would appear to have more time in these components to engage in other activities allowing either satiation or reinforcer reallocation to occur.

Taking another Look at the Status of Responding

Hinson and Staddon (1978) noted the peculiarity of the VT experiment, providing an explanation that is not only adequate but which is also plausible. That is that VT and VI signaled schedules induce behaviors that are specific to that particular schedule and these are just as robust, occupying as much of the animals time as, as the actual key peck response. A similar phenomenon as that seen in the superstitious behaviours observed by researchers. Staddon and Simmelhag (1971), carrying on from earlier work by Skinner conducted a number of superstition experiments. The main finding that is relevant here was that certain behaviour patterns would occur more frequently than others in different subjects during intervals between food delivery. They argued the response contingency may be irrelevant to the amount of behaviour maintained by the reinforcer. It is now accepted that some behaviours can increase in frequency because of their pairing with the reinforcement (Mazur, 1993, pg.120).

Hinson and Staddon argue that these behaviours compete with R_o to the same degree as responding in the varied component. Thus although the animal is no longer spending its time key pecking a new behavior has entered the animals repertoire due to random pairing with the reinforcement. This behavior is taking the time that was previously spent responding, thus the reinforcement schedule may be irrelevant to the level of operant behaviour that occurs in the varied schedule. Thus the responding itself does not have any special status, rather it is reinforcer contingent behaviour, which responding is part of, that is crucial to contrast. This line or reasoning provides the explanation the competition theories need to explain the failure to observe contrast with the VT and VI (sig) procedures.

Williams and Wixted (1994) argue that the development of some new category of behaviours is designed solely to save the behavioural competition theory. They also raise the valid question as to why this 'other behaviour' does not decrease with the response when signaled VI is introduced. The problem is that all behavior that is being maintained by the reinforcement provided by the experimenter (be it pecking or what ever else) is not being reinforced when the signal is absent in the signaled VI or at any time in the VT. Thus whatever it is that is discouraging the animal from responding should equally discourage this other behavior. Williams and Wixted do not explicitly state that behaviour in the extinction component should be similar to behaviour in the VT or VI (sig) component. However this assumption can be drawn from their argument. They do state that during extinction the animal is free to engage in any "other behaviour" to gain these extraneous reinforcers, a point which both theories agree on. Williams and Wixted then go onto claim that, because in the VT component, reinforcement is not contingent on responding then the animal is also free to engage in these other behaviours. Therefore, by the above logic there should be similarities in the behaviour patterns in the components in which reinforcement is not contingent on responding, and in components in which there is no reinforcement. Because contrast is not reliable in these procedures, the competition theories are reliant on behaviors emerging in the VT/VI (sig) procedures that are not present in either the Baseline or Extinction conditions.

Behaviour in the Operant Chamber

There has not been a vast amount of previous research examining what behaviours the animal engages in the operant chamber, yet alone while specific schedules are operating in this chamber. The first well-documented attempt to do this was conducted by Skinner (1948) in a now famous experiment often referred to as the superstition experiment. Skinner placed 8 pigeons in experimental chambers delivering them food regardless of what the animal was doing every 15 seconds (VT 15). For 6 of the 8 animals Skinner documented clearly defined behaviours that occurred between food presentations. For example one animal developed pecking motions at the floor, another would toss its head in an upward motion. Skinner deduced that these 'superstitious behaviours' developed due to accidental pairing of the behaviour with reinforcement, thereby increasing the probability of the behaviour being exhibited and as such increasing the probability of future pairing with reinforcement.

However Skinner's analysis of the behaviours emerging in the operant box is not the only theory that has been proposed. Staddon and Simmelhag (1971) conducted a similar experiment replicating Skinners results with a more thorough investigation and coding system for categorizing the behaviour occurring in the schedules. The authors used both Fixed Time schedules and VI schedules. Upon coding they found that the animals activities in the operant box could be grouped into two classes of behaviours. These were referred to as interim and terminal behaviours. The authors defined interim behaviours as those occurring early in an interval, thus when reinforcement was likely to be some time away. Terminal behaviours were those occurring toward the end of an interval when probability of reinforcement increased.

Staddon and Simmelhag (1971) observed many of the same behaviours as Skinner had referred to as Superstitious Behaviours, such as pecking grill and moving along the interface wall, however unlike Skinner they referred to many of these behaviours as interim behaviours. These behaviours were seldom followed by reinforcement thus Staddon and Simmelhag deduced that they were behaviours that the animal had a predisposition to perform when the likelihood of reinforcement is low. Thus they are behaviours maintained by extraneous reinforcers. Therefore, not all behaviours that occur when periodically free reinforcers are delivered are the result of accidental pairing with the reinforcer. Some may be innate behaviour that occurs when the probability of reinforcement is low. However it seems just as logical that some of these behaviours can be maintained by the accidental pairing of the occurrence with the presentation of reinforcement. Staddon and Simmelhag view this adventitious reinforcement as being problematic as it implies a failure of constancy. That is the animal is presumed to be unable to distinguish between real and accidental correlation between their behaviour and the occurrence of reinforcement. The authors did concede that, in cases of only a few instances of the behaviour, due to sampling limitations transient superstitious effects could occur. However they claimed it was not convincing as an account of the long-term effect.

The issue for the current debate is what behaviours develop when different reinforcement schedules are run. In the baseline phase reinforcement is contingent on responding. In the VT (and signaled VI, although some contingency still exists) reinforcement is made non-contingent on responding. Finally in the extinction phase there is no reinforcement, hence no contingency. One key aim of the current experiment

then was to compare behaviours the animal engages in across these different contingencies. This needs to be done in order to compare the non-key pecking behaviour that emerges in each of the conditions. If behaviour that emerges in the signaled VI or VT conditions then disappears in the EXT condition this effectively eliminates Williams and Wixted's line of argument. However if similar behaviours occur during both the signaled VI and VT conditions that occur in EXT then this is damning evidence against competition theories of contrast since there is no reason why reallocation would not occur during the VT and signaled VI condition.

The problem previously was that no one had ever tried to examine these other behaviors that develop with respect to contrast. The current research explored the behaviour of the animal in the components by actually viewing what the animal was doing and categorizing this behaviour. If the animal was to develop any superstitious behaviour this would be detected in the tapes since behaviour would be present during non-contingent reinforcement that was not present during extinction. In conjunction with these data, Inter Response Times were recorded down to hundredths of a second. Inter Response Times (IRT's) allow the experimenter the opportunity to study an animal's behaviour at a molecular level examining individual responses, and the exact time it made the animal to elicit them.

CURRENT RESEARCH

The aims of the present research were:

1. Replication of numerous condition changes in the multiple schedule. This includes mult VI VI to mult VI VT (or VI(sig)), mult VI VT (or VI VI(sig)) to mult VI EXT, and finally mult VI EXT to mult VI VI. This examines firstly the effect of decreasing the response rate while holding reinforcer rate constant. The second manipulation involves decreasing reinforcer rate while holding response rate constant. Finally the change from no reinforcement to baseline is conducted to both check on the reliability of previous contrast if observed and to record the baseline for the condition change.
2. Analysis of response typographies (inter response times) to see the effect of signaling reinforcement, delivering free reinforcement, or not delivering reinforcement has on IRT distributions
3. Categorize behaviors in VI, VI(sig), VT, and EXT and make comparisons of behaviour in the three contingencies. While the contrast phenomenon was the topic of interest that spurred on the experiment, the more general question of what animals do in different conditions is interesting from a number of areas of the experimental analysis of behaviour. For this reason it is somewhat surprising that more attempts have not been made at categorizing behaviours in the operant chamber. Clearly the intense and monotonous requirements of the study, in terms of coding hours of pigeon sessions, has subdued peoples interest in the fundamental question of what

the animals do in the operant box. A more thorough understanding of this will assist in all theories of learning, be it matching, autoshaping or contrast.

The research then can provide a number of important elements to the debate. It can verify whether there is contrast in the VT and VI(sig) procedures, an area where there is continued conjecture. It can outline the behavioral repertoire (from the tapes) and response patterns (from the IRT distributions) for each of the components, that is variable interval, variable time, signaled variable interval and extinction components. And finally it can assess what behaviours emerge, and how these change, across different contingencies.

Method

Subjects

Four, experimentally naive homing pigeons were maintained at 80 to 85% of their free-feeding body weights for the duration of the experiment. Water and grit were continuously available in their home cages, where supplementary food was provided after each days session to maintain each animal's prescribed body weight.

Apparatus

A single experimental chamber was specifically designed for the purpose of the experiment. Due to the lighting requirements of the procedure the roof and one wall of the chamber were made of glass, and the door of the chamber was clear perspex. The chamber (which measured 34cm by 30cm by 32cm) contained a control panel with three keys mounted on one wall. Each key was 2cm in diameter and 24cm above the wire mesh chamber floor. The center key was located 16cm from each wall, with the other keys located 8cm either side of this. During the sessions only the two side keys were active and illuminated.

The left key was illuminated green, the right key red or a combination of red and green. Each key required a force of approximately 0.15N to register a response.
Two hoppers containing clean wheat were mounted behind the control panel, with one beneath each of the side keys. The hoppers, operated separately, were raised to an opening 5cm wide and 4.5cm tall when a reinforcer was delivered. At this time the

interface panel lights went off and a white light from behind the hopper came on. The opening for the hoppers was 5cm off the floor. At all other times the hoppers were inaccessible to the subjects.

The chamber was equipped with a fan, which both ventilated the chamber and masked any external environmental sounds. Scheduling and recording of all experimental events was conducted using an IBM 386 CPU compatible running MED-PC® software and using MED Associates interfacing. This was located in the experimental room out of view of animals in the operant chamber. Videoing of the animals was achieved using a Sony flexy cam, attached to a Phillips VCR. Each animal was run at approximately the same time each day.

Procedure

The general procedure used in the experiment closely followed the standard procedure for behavioural contrast studies as mentioned above. That is a multiple schedule procedure consisting of a baseline phase, in which equal variable interval schedules were used in the components, and a discrimination phase, in which component 1 remains unchanged and the reinforcement conditions in component 2 vary.

The session comprised a two component multiple schedule. Each component lasted for one minute plus an additional three seconds for any reinforcers delivered. There were 40 components in the session, thus lasting for just over forty minutes.

Since all animals were nieve at the start of the experiment the key peck behaviour was shaped and the animals were gradually exposed to the VI schedule that

would be used in the experiment. Following this a lengthy baseline was initiated to familiarise the animals with the mult VI VI. At this stage the animals were exposed to the new chamber. Because of the need to have full lighting in the room during the session the animals were gradually exposed to increasing amounts of illumination in the room. The light level was increased when responding had sufficiently recovered from the usual down turn with the new light level. After sufficient lighting was achieved the baseline period was begun, although the animals had experienced the same conditions for some time.

The animals were exposed to a 2 component multiple schedule. The left key was illuminated green and operated the hopper directly below according to a VI80 condition. The right key, which would serve as the varied component, was illuminated red and at first was also operated by a VI80 component. The conditions used in the experiment, and the number of sessions of each is presented in Table 1.

Table 1: Experimental Conditions

	Date (1997-1998)	Number of Sessions	Component 1 Constant Groups 1 & 2	Component 2 Varied Group 1	Component 2 Varied Group 2
Condition 1	6 Oct-23 Oct	18	VI 80	VI 80	VI 80
Condition 2	24 Oct-9 Nov	17	VI 80	Sig VI 80	VT 80
Condition 3	10 Nov-24 Nov	15	VI 80	EXT	EXT
Condition 4	25 Nov-11 Dec	16	VI 80	VI 80	VI 80
Condition 5	12 Dec-31 Dec	19	VI 80	VT 80	Sig VI 80
Condition 6	1 Jan-16 Jan	16	VI 80	EXT	EXT
Condition 7	23 Jan-16 Feb	24	VI 80	VI 80	VI 80
Condition 8	17 Feb-1 Mar	12	EXT	VI 80	VI 80

Once the animals responding stabilised, or after around 15 sessions of the new baseline the animal's behaviour was recorded using a video camera for the final three sessions. These days would serve as the test days for the data analysis using both the Inter Response Times and the videotapes.

The first condition was signalled VI80 for two of the animals and Variable Time 80 for the other two. In the signalled VI the left key was signalled red when the component was active, however when a reinforcer was set up the key colour became a combination of red and green, or a light yellow. At this point the first response would be reinforced. The other condition was variable time in which case the red key signalled the condition was in effect and food was dispersed irrelevant of the animal's behaviour. Again the last three days of the condition were recorded and the behaviour was analysed using the IRT's and the videotapes. The final manipulation was a change to extinction in the varied component. At this stage the red key signalled that there was no reinforcement available for responding.

Following this the animals were returned to baseline VI-VI which served as both a check on the previous contrast effect, if present, as well as providing the criterion for the next run through the manipulations in which the conditions for the four animal were reversed. Prior to these conditions the animals had been exposed to one earlier complete cycle. However due to the variability of the response patterns that were recorded throughout the entire cycle, the first trial was scraped and the experiment started again (see Table 1 for experimental conditions and number of sessions each was in effect).

The animal's Inter Response times where recorded in hundredths of seconds for each session. As mentioned the last three days of each session used as test days for the

study of the animals inter response times. These could be analysed at a later stage to look for response patterns. The animal's behaviour was also analysed using the taped videos of the animal in each of the phases of the experiment (again the last three days of each condition served as the test days). The tapes were first viewed to work out a classifying system to code each animal's activities while it was in the active chamber. The behavioural repertoire of each animal could be captured using around half a dozen categories designed to capture the overall behavioural typography. These behaviours, presented in Table 2, were used for each animal however there were some differences in the way each performed the behaviours. For example each animal had a different way of strutting the interface, some with its head stretched to the roof, another looking directly at the keys, however all strutted along just in front of the panel remaining oriented to the hoppers.

Once the individual behaviours where categorised the tapes were viewed with a stopwatch and the time spent occupied in each behaviour was recorded. While this proved to be a somewhat lengthy procedure it did have some merits in that it enabled a first hand look at the behavioural patterns as well as the superstitious behaviours that have often been reported in previous papers. Each animal's individual behaviour repertoire was modified to account for individual differences. Descriptions of individual animal's behaviours are provided in the result section where they were specific to the individual. Reliability of the measure was assessed by having a post graduate student, familiar with operant psychology however unfamiliar with current aims, categorise the animals behaviour in the chamber without any assistance on devising categories. Due to the need to get a check on any change in behaviour across conditions it was decided to

follow one animal through all conditions doing one tape for each condition. That is six tapes (of the 18 available) were checked for animal D5. The results of these are presented in Appendix A.

Table 2: Working Definitions of Behaviour Categories

Key pecking on active key: Animal is oriented to key and is involved in repetitive, continuous responding on the active key.
Time to start responding: Following Multiple Schedule changes, the time it takes the animal to produce its first response
Post reinforcement Pause: Following reinforcement, the time it takes the animal to produce its next response.
Bopping on active hopper: Orienting to key but not responding, rather moving head in repetitive manner between active key and hopper.
Bopping on other key/hopper: Not responding, moving head in repetitive manner between active key and inactive key or hopper.
Strutting interface wall: Not responding, moving entire body in repetitive movements along the interface wall
Strutting metal wall: Not responding, moving entire body in repetitive movements along adjacent metal wall.
Not orienting to interface wall: Facing away from the interface wall, however not engaged in repetitive movements.
Scratching: consists of; *Wingflapping*: Animal extending its wings and flapping them, *Grooming*: Scratching own body with either its claw or beak, and *Grill Pecking*: Pecking at the grill mesh floor.
Frustration: Rapid boping, wingflapping and jumping at back window.

As noted previously the animals received a substantial baseline (VI-VI) period before the first condition. The reason for the lengthy exposure was that the lighting in the room was gradually increased in order to allow high quality videoing to occur. After the lighting was at a sufficient level the recorded baseline began. However as the animals weights were well above the 85% without any post session feed, the VI schedules were changed from VI60 to VI80 allowing more control over the animals weight. Following this the animals received 20 baseline sessions with the last three being recorded using the video. It was intended that these three days would provide the criterion from which to assess the rest of the conditions response patterns, inter-response

times and video tapes. However it became blatantly apparent that the first baseline was not stable enough to allow meaningful analysis of response patterns. For this reason the entire first run, including baseline was repeated. With the second run a more stable baseline was achieved. Thus the result was that the manipulation changes that were produced were more likely the result of the changing conditions rather than the result of the fluctuating baseline.

Results

As mentioned there were primarily three areas of study. Firstly, the overall response rates across the changing conditions are of interest for the contrast debate. Secondly, the inter-response time data used to analyze the typography of patterns of responding, and finally there were the videotapes, 18 sessions for each of the four animals, allowing analysis and description of behaviour patterns under different contingencies. Thus, the current experiment could examine changes in response rates, changes in the animal's response topography and reveal the appearance of any other behaviors, not normally part of the animal's behavioural repertoire.

Overall Response Rates

The primary objective of the experiment was to test whether contrast was observed when a two component multiple schedule changed from mult VI VI to mult VI VT or mult VI VI(sig), and whether contrast occurred with the further change to mult VI EXT. Contrast has been observed regularly when baseline mult VI VI changes to mult VI EXT. However the current procedure focused on the more controversial manipulation of changing from mult VI VI too mult VI VI(sig) or mult VI VT conditions, allowing the separation of reinforcement and response rate in testing for contrast. The purpose of the manipulation is to further examine the relationship between contrast and the relative rates of reinforcement. Since the above manipulations result in no change in the relative reinforcement rates, only the animal's behavior changes when conditions are changed. Traditionally the change has been documented as a substantial decrease in the animal's response rate. That is, the manipulation should produce a decrease in responding in the varied

component. Whether it also produces a change in the constant component will reveal whether the transition to non-contingent reinforcement or non-contingent signals produces contrast. The second manipulation involved the change from mult VI VT or mult VI VI(sig) to mult VI EXT. This is a less common manipulation. Because the VT and VI(sig) procedure already produces the low response rates in the varied component, this manipulation results in a change in the reinforcement conditions only. Prior to this, both components were arranging the same rate of reinforcement, after the condition change only responding in the constant component is reinforced by the experimenter. Responding in the varied component should remain low, since no reinforcement is available. Responding in the constant component will reveal whether contrast occurs with a change in the relative reinforcement rates. Finally mult VI EXT became mult VI VI, a return to baseline. Any possible contrast effects that had been observed could be measured against this.

Figure 8 shows average responses per minute for each animal in each session. The solid line indicates constant component responding and varied component responding is indicated by the dotted line. Contrast would be displayed by a rise in the solid line level when conditions are varied (indicated by a break in the line). Appendix B shows the raw data, displayed in average response rates per minute for the first and last five sessions of each condition.

As can be seen in the top panel of Figure 8, D5's response rate in the constant component remained relatively stable throughout both manipulations despite the varied key response patterns fluctuating appropriately throughout. The one exception to this was the clear signs of transitory contrast following the change from mult VI VT to mult VI EXT. Characteristic of this effect was the initial elevation of response rate (up to 20 responses per minute more) which declined across sessions

leveling off at (approximately) baseline levels by the end of the condition. This effect was not repeated with the subsequent change from mult VI VI(sig) to mult VI EXT although the first result was large enough to suggest that it was a genuine display of transitory contrast and not an artifact of a fluctuating baseline.

Bird D6, like D5, did not produce a contrast effect with the change to VT. In fact, if anything the effect here was one of induction; constant-key responding also declined following the condition change. There is some suggestion of a slight contrast effect with the change from mult VI VI(sig) to mult VI EXT. Here, although the increase is moderate (around 10 responses per minute), it is sustained across the extinction component, disappearing with the reintroduction of the baseline phase (see appendix for mean data confirming this).

Bird D7 produced moderate (constant key) contrast effects with the introduction of both extinction components, although both were transitory to differing degrees. There is also some possibility of very slight contrast effects in constant key responding with the introduction of both the VT and the VI(sig) components.

Finally, as can be seen by Figure 8, it is hard to deduce anything from D8's performance as responding never stabilized following the first condition change.

In summary neither the change to VT or the change to VI(sig) produced reliable contrast. While it is clear the animals were sensitive to the change by the substantial decreases in responding in the varied component, this change did not produce contrast effects in the constant component. The change from these conditions to extinction produced mild to moderate contrast (often transitory) in some instances, but not reliably over repetitions.

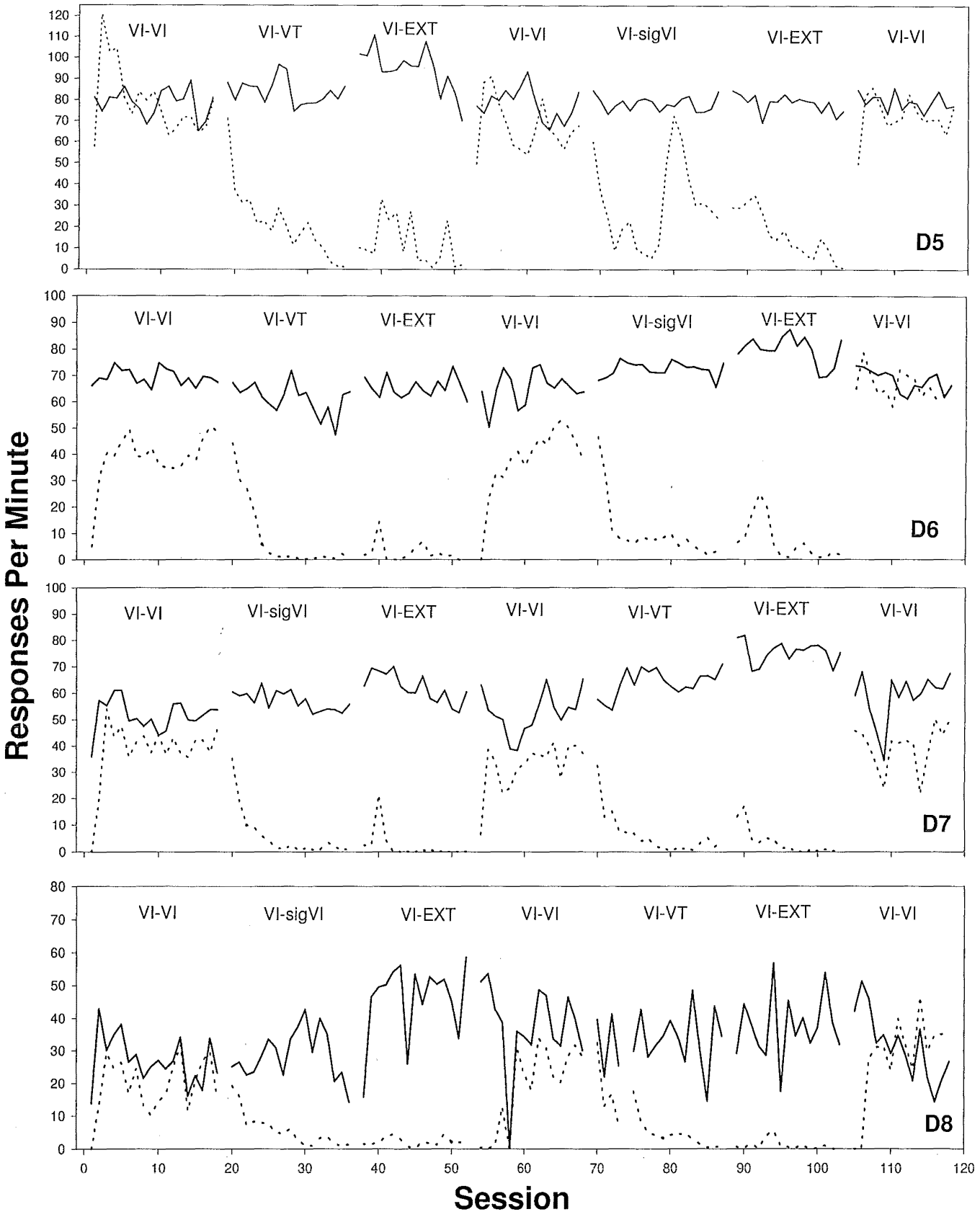

Figure 8. Absolute response rates across sessions for each animal during both trials of experiment. Responding converted to responses per minute, components indicated by a solid line (constant component) and a broken line (varied component). Break in the lines indicates a change in conditions.

Contrast using a traditional manipulation

Following the failure to observe sustained contrast in either of the earlier conditions it was decided to check the sensitivity of the procedure to detect contrast by using a traditional contrast-producing change, that is the change from mult VI VI to mult VI EXT. In addition the components were reversed to compensate for any practice effects from the last several months of conditions. These results are presented in Figure 9. D5 showed a moderate increase of approximately 10 responses per minute in the constant component over the first 10 sessions. However, response rate leveled off after this at levels similar to those seen in the initial baseline. Similarly D6 also demonstrated some initial elevations, up to twenty responses per minute on this occasion, however like D5 this subsided after 10 sessions. Both D7 and D8 produced relatively stable responding, possibly on the side of a mild contrast effect although within limits of ordinary baseline fluctuations.

Analysis of Videos

Analysis of the videos began with the production of a list of characteristic behaviours the animals engaged in during time in the operant chamber. This was achieved by simply watching some of the tapes and noting what types of behaviours were engaged in. Following this each tape was observed with a stopwatch and the amount of time engaged in different behaviours was recorded. As this required numerous amounts of stopping the video and rewinding back to code all behaviours, this method proved to be very labor intensive. The categories that were devised by the experimenter are given in the method. Appendix A describes an attempt to examine the reliability of the measure by having the procedure repeated by another observer.

Figure 10 (a and b) contain the varied component behaviour patterns coded for the four birds. Constant component behavior was also coded and graphed for each of the animals. However behaviour in the constant component was shown to be very consistent despite the varying conditions in the varied component (see Appendix C for confirmation of this). How the animals adjust behaviourally to the loss of contingencies in the varied component is still of interest and is still an important issue in the contrast debate. It is the changes in the varied component that are of utmost importance here, since this component is most effected by contingency changes. However average data for each three-session condition is presented in Appendix C for those interested. As discussed in the introduction, a critical difference that can be deduced between the theories of contrast concerns behaviours in different schedules. Williams and Wixted (1994) claim that the animal is free to engage in "other behaviours" reinforced by R_o, in the VT and signaled VI conditions, just as in the extinction condition. This is because there is no constraint made on responding by the contingency in either of these conditions. Therefore they claim that those manipulations should, according to competition theory, produce contrast. Contrary to this, the competition theories might argue that the other behaviours that emerge in the signaled VI and VT conditions are reinforced by the experimental reinforcers; thus they do not engage in the same activities as in the extinction condition, therefore contrast does not generally occur.

As can be seen from Figure 10a bird D5 spent around 60 percent of its time in the varied component key pecking when baseline conditions (VI 80-VI 80) were in place. This, in addition to strutting the interface (around 30 percent of the time), basically occupied the animal's time for each of the one-minute components. From

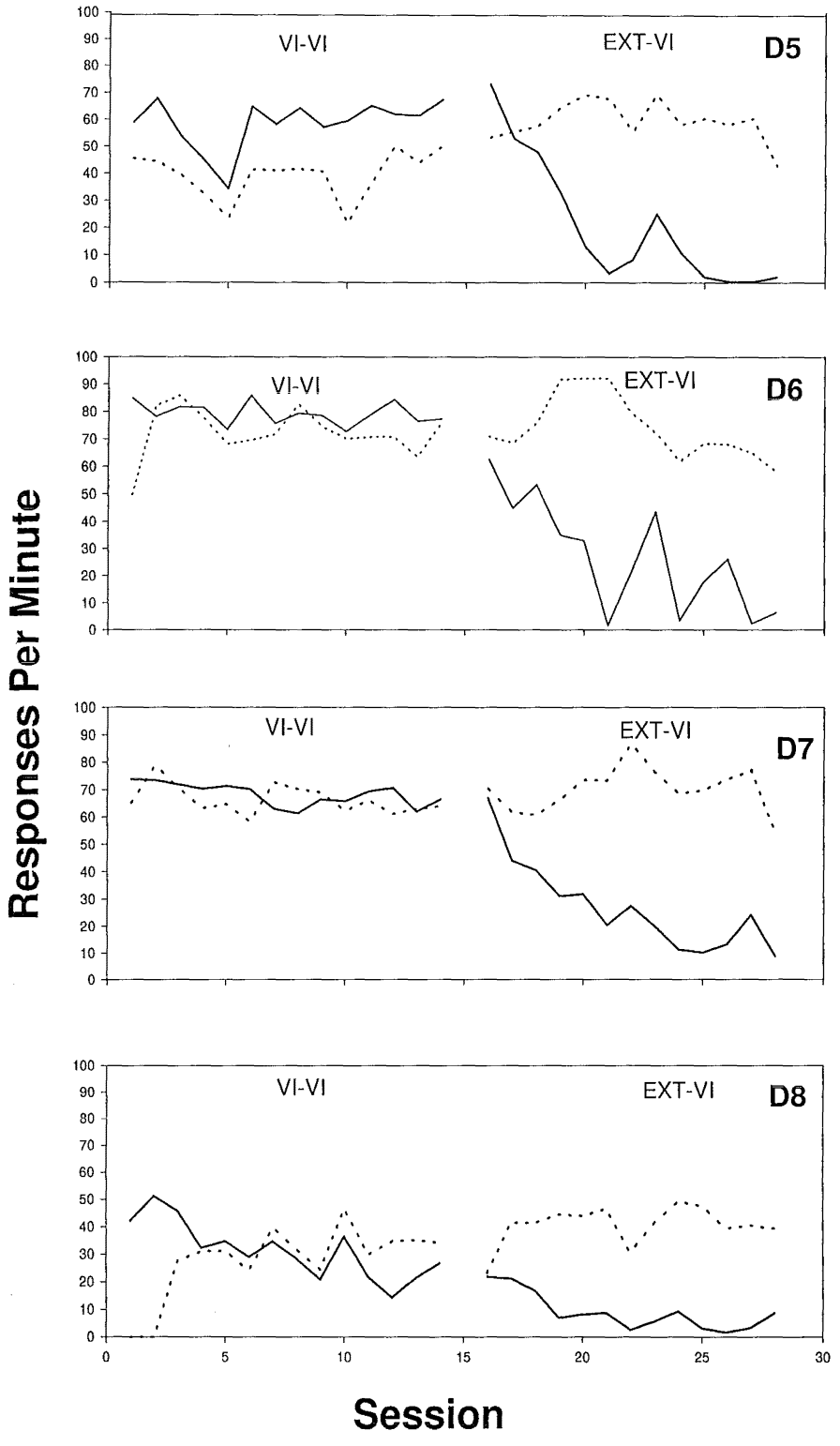

Figure 9. Absolute response rates across sessions for each animal during extinction only phase of experiment. Responding converted to responses per minute, components indicated by a solid line (now varied component) and a broken line (now constant component).

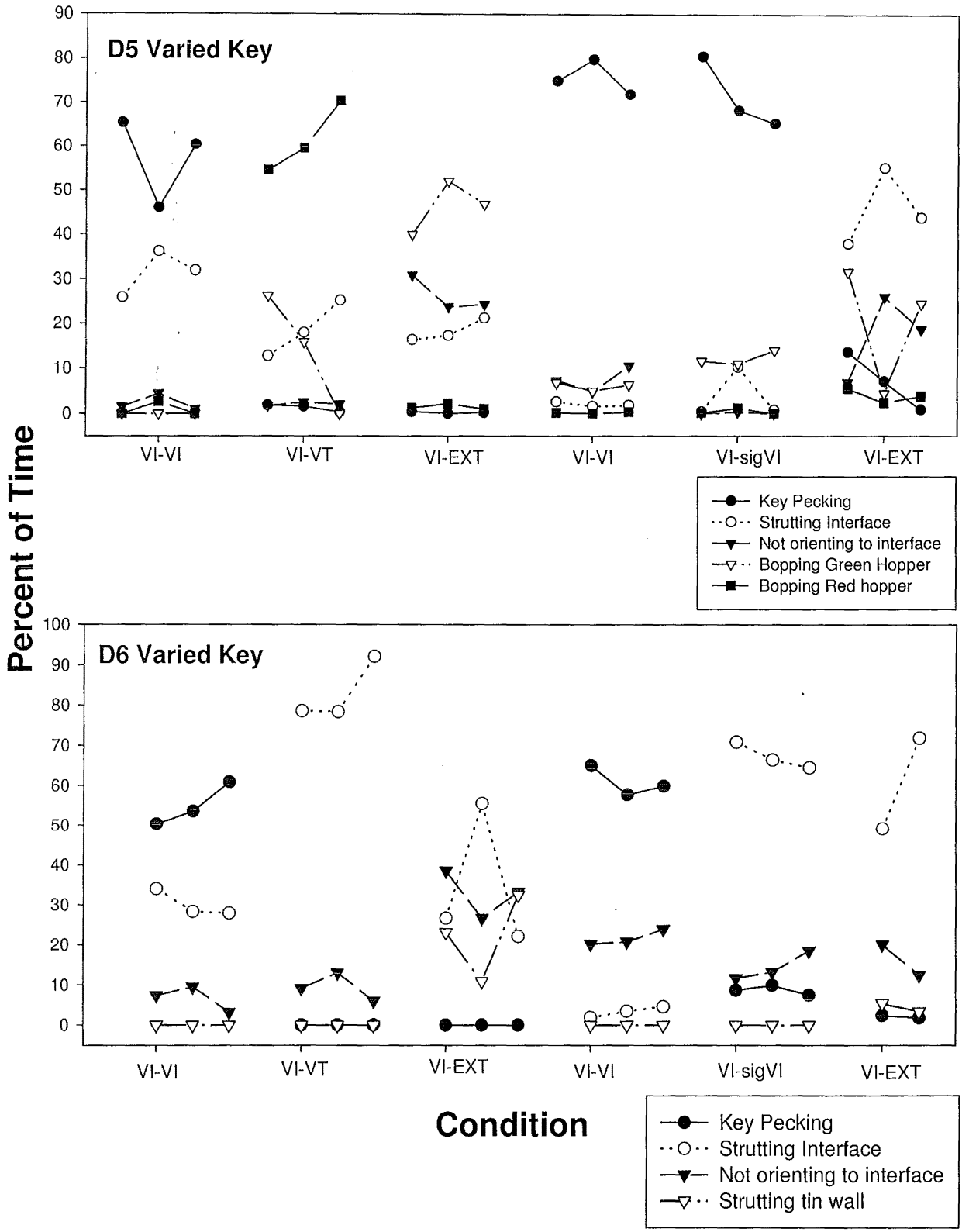

Figure 10a. Percent of time spent engaged in different activities during the varied (red key) component in the different conditions for birds D5 & D6. Note that not all behaviours engaged in are displayed in the graph.

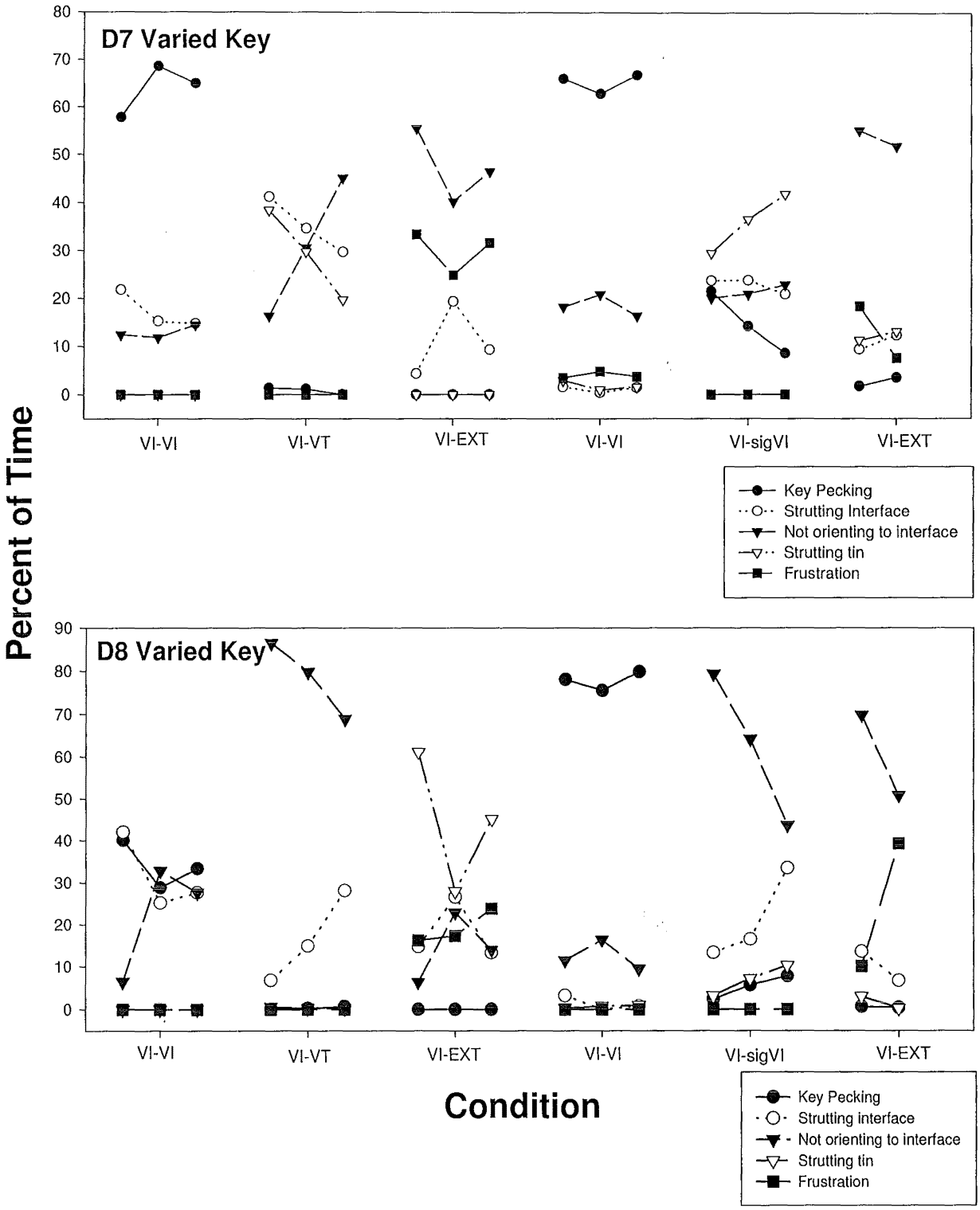

Figure 10b. Percent of time spent engaged in different activities during the varied (red key) component in the different conditions for birds D7 & D8. Note that not all behaviours engaged in are displayed in the graph.

Appendix B it can be seen that during this time the animal was responding at approximately 70 responses per minute. The change to the VT condition eliminated time spent key pecking, and instead the animal spent around the same proportion of time as was spent key pecking bopping around the red (active) hopper. Strutting the interface remained prominent, although not as much as in baseline, and in addition bopping the green (inactive) hopper also emerged as a distinct behaviour.

The addition of the extinction component eliminated time spent bopping around the red hopper, which is now inactive due to extinction. Instead the animal spent around 50 percent of its time bopping around the green hopper. Also, for the first time, orienting away from the interface emerged as a behaviour that accounted for a reasonable proportion of the animal's time (approximately 25 percent) with strutting the interface making up another 20 percent (approximately).

With the return to baseline conditions again key pecking emerged as the primary behaviour, this time occupying around 80 percent of the animal's time. It remained the primary behaviour with the addition of the signaled VI component and it was not until the addition of the extinction component that the behavior disappeared. Here strutting interface (around 45 percent), Bopping green hopper (25) and not orienting (25) were the primary behaviours.

D6 spent approximately 60 percent of its time key pecking in both baseline conditions. The rest of the time was primarily made up with strutting the interface in the first baseline, and not orienting to the interface in the second. During the VT condition time spent strutting the interface increased to approximately 85 percent of the animals behavioural output. Time spent not orienting to the interface stayed relatively constant at just under 10 percent. With the removal of reinforcement in the extinction component strutting interface decreased to a level similar to that in

baseline, time spent away from interface increased to its highest level of around 35 percent, and a new behaviour of strutting the side wall emerged. This last behaviour occupied around 20 percent of the animal's time. Following the second baseline, where key pecking was again prominent, strutting the interface again emerged as the primary behaviour with the introduction of the signaled condition. Orienting away from the interface, and key pecking made up the rest of behaviour during this condition. This remained relatively constant with the introduction of the final extinction condition. One behaviour not graphed although of some interest was time spent scratching, grooming, wingflapping, and grill pecking which can be seen in Appendix C (Category 6). These behaviours were collapsed into the one category (scratching). Here 9 percent of the animals time in the first extinction and 11 percent of it time in the second extinction condition were spent 'scratching' relative to basically zero in the associated constant green key (VI) condition. It is also clear that there is no other time across the contingencies when time spent 'scratching' is anywhere near this high.

Figure 10b presents the results for bird D7. Consistent with the other animal's, D7 spent most of its time engaged in key pecking. In addition, and similar to other animals, strutting the interface and orienting away from the interface make up the remaining portions, both under 20 percent of the animals time. Again, the addition of non-contingent reinforcement, in the form of signaled reinforcement on the first occasion, eliminated the key peck response. In its place, strutting interface, strutting tin, and orienting away each occupy around a third of the animal's time. With the addition of the extinction component in its place not orienting increases to around 50 percent, strutting interface decreases slightly (to around 15 percent) and the new category of frustration emerges for the first time. Here the animal has spent

around a third of its time in the extinction component bopping, and jumping around at the back of the chamber (against the door). The behaviour was labeled 'frustration' as these activities occurred at an increased pace and in a manner suggesting the animal was frustrated. For example the animal would throw itself against the perspex door, and jump around from side to side, all the while flapping its wings and bopping its head rapidly. This behaviour was specific to D7 and D8 where by around the 20th component in the extinction sessions (that is half way) frustration usually set in during the red-key component which, by the end of the session, was virtually controlling all of the animals time. This behaviour would occasionally spill over into the constant component although not with the same frequency, duration, or intensity. Upon return to baseline conditions key pecking reemerged, with orienting away from the interface the only other behaviour to feature prominently. Again the VT condition produced strutting tin and strutting interface to emerge which, with orienting away and key pecking remaining, made up the behaviours in this condition. With the re-introduction of extinction orienting away from the interface stands clear as the behaviour of preference with around 55 percent of the time spent engaged in this. Frustration, strutting interface, and strutting tin, occupy the rest of the animals time in approximately equal portions.

As mentioned earlier, D8 failed to produce consistent responding in either the constant or the varied components. Bird D8 also developed some bizarre key peck rituals, which slowed down its rate of responding. These involved pecking and walking around, as if to complete a circle, however upon half way through the circle turning back and going back to respond again, and so on. This behaviour occupied a large portion of the animals time and can be identified by the animals lack of short IRT's.

The first behavioural observation of D8 occurred in baseline conditions. As can be seen in Figure 10b during this period key pecking, strutting the interface, and orienting away from the interface each occupied approximately 30 percent of the animals time. Time spent orienting away from the interface increased markedly with the change to the signaled VI condition, strutting the interface time decreased slightly, and key pecking vanished altogether. The change to extinction produced four prominent behaviours with frustration joining strutting the interface, orienting away from the interface, and strutting the tin (which appears as the most frequent). With the change back to baseline conditions key pecking emerged as the dominant behaviour, more so than in the first baseline condition. Not orienting to the interface remained at around 10 percent however the rest of the behaviours practically disappeared. The reintroduction of non contingent reinforcement, in the form of VT on this occasion, resulted in the dramatic elevation of orienting away from the interface (60 percent) and to a lesser extent strutting the interface (20 percent), and strutting the tin (less than 10 percent). Key pecking did remain present, although at levels slightly less than the level of tin strutting. The final extinction condition produced an increase in frustration, as before, and a decrease in other activities.

In summary, the main finding of the analysis of the videos was that during the VI condition behaviour in the chamber is dominated by key pecking. With the change to non-contingent reinforcement behaviour is mixed with strutting the interface, strutting the tin and bopping the hoppers generally being dominant. Finally the change to no reinforcement sees an increase in behaviour that is not oriented towards the interface and in some instances the emergence of behaviour identified by this experimenter as characteristic of frustration.

Inter-Response Times

The inter response times provide an accurate breakdown of the animals response patterns in the different conditions. By examining the patterns the experimenter can develop a rough breakdown of the animals response topography and a molecular analysis of how the animal spends its time in the chamber. Figures 11(a-d) present the IRT distributions up for each of the animals. Each response recorded within two seconds of the previous response (or the start of the component) is plotted. No responding after 2 seconds is plotted, although it is used to calculate the proportion of responses that occur in each time period presented. Responding in each component is presented although the constant component pattern is of primary interest. The IRT distributions for the varied component during times of non contingent reinforcement (VT and signaled VI) and times of extinction are of little interest as response rates were so low. Figure 12 presents constant component IRTs for the first three days of the extinction condition in both trials. An asterisk indicates components where contrast was observed.

Figure 11a presents D5's IRT distributions for both components and for all conditions. As can be seen from the graph this animal has a substantial peak in its IRTs between 60 and 70 hundredths of a second, that is 0.6-0.7 seconds. It appears then that this animal has developed a green (constant) key pattern of inter response behavior that lasts for 0.6 of a second. Note that the animal did not engage in this same pattern in the presence of the red (varied) key in baseline when conditions were equal. It appears from the graphs presented that the response topography did not change over the conditions. D5 showed no change in response frequency (in either direction) when the varied component was changed to a variable time schedule (see Figure 8), thus no change in the distributions would be expected. D5 did show

contrast in the extinction condition however as noted by the end of the 15 days this contrast had gone and the graph presents only the last three days of the condition. Figure 12 presents the first three days of the extinction condition where as mentioned contrast was clearly evident during the first introduction. Again this distribution has the peak at 0.6 seconds, in addition though there was an additional peak at around 0.35 seconds. This 0.35 second peak was not present in the second trial, where contrast was not observed.

As can be seen from Figure 11b D6 produced a large number of IRTs of between 0.8-0.9 seconds, and a smaller sharper peak at 0.1 seconds. The analysis of the videos revealed that D6 had a response pattern consisting of responding, then looking up and across toward the center key (that was never active during the current experiment) and then responding again. A sample of these responses taken from the video with a stopwatch revealed that this behaviour was responsible for the cluster of IRTs at around 0.85 seconds. As noted, (see Figure 12) this animal demonstrated a downturn in responses when the varied component became variable time. This may have been related to the lower peak at 0.1 seconds in the IRT distributions. This 0.1 second peak recovered in the extinction condition. Figure 12 reveals that when the animal was first exposed to extinction, minor rises in responding around 0.3 seconds and 0.1 seconds were observed.

D7 showed a consistent pattern throughout the constant components in the experiment, that was a multi-modal IRT distribution. As Figure 11c presents there a 5 mini peaks that remain consistent for this animal occurring before the first second has elapsed. These peaks occur at approximately 0.1, 0.3, 0.5, 0.75, and 0.95 seconds regardless of differing conditions in the varied component. Analysis of the videos for this animal revealed that D7 interspersed pecking with looking up towards

the top of the chamber, directly above the key. Given that the amount of time the animal spends doing this was very variable this may account for this multi-modal distribution.

Again Figure 12 shows the first three days of the extinction condition. The graph appears very similar, the peaks have risen slightly, that is they now command more of a proportion of the animal's total IRTs but they are all still located in the same place temporally. It would appear then that the animal was spending its time on task responding more rapidly.

Finally D8's IRTs are presented in figure 11d. Because the animal had a very low response rate it is unlikely many responses were made in the first second as proved to be the case. In the extinction condition where the animals constant component responding increased substantially, there is evidence of a 0.3 second cycle appearing with peaks at 0.3, 0.6, and 0.9 seconds. It is the higher proportion of these responses that may be responsible for the contrast effect. Responding during the experiment for this animal was very unstable however.

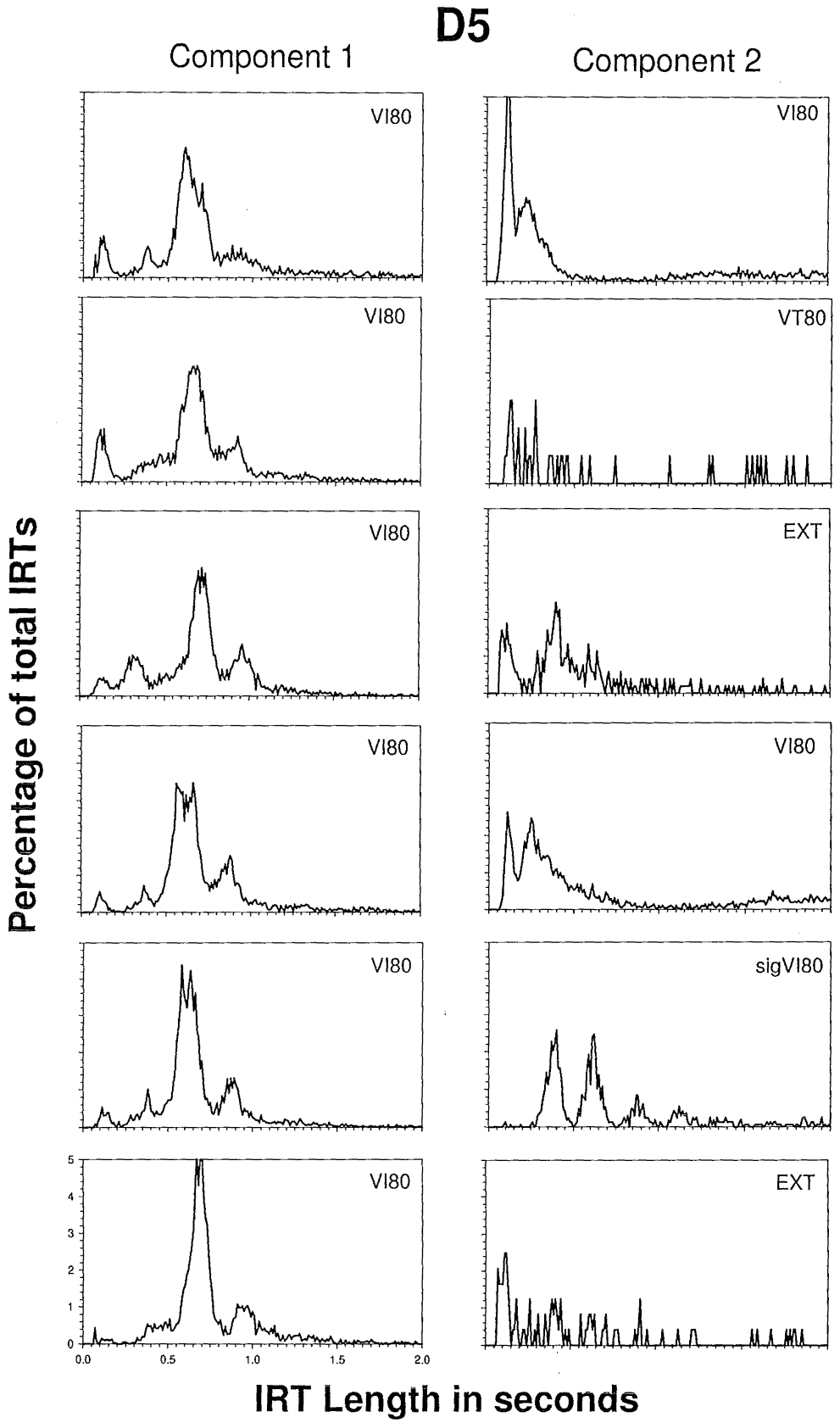

Figure 11a. IRT distributions for the constant component (left column) and the varied component (right column) for bird D5. Each row gives data, averaged from the last three sessions of each condition. The ordinate on each graph shows the percentage of the total number of IRTs (ranging from zero to five percent) with minor ticks at every 0.2 percent. The abscissa on each graph is the length of IRTs and ranges from zero to two seconds with ticks at every 0.05 seconds.

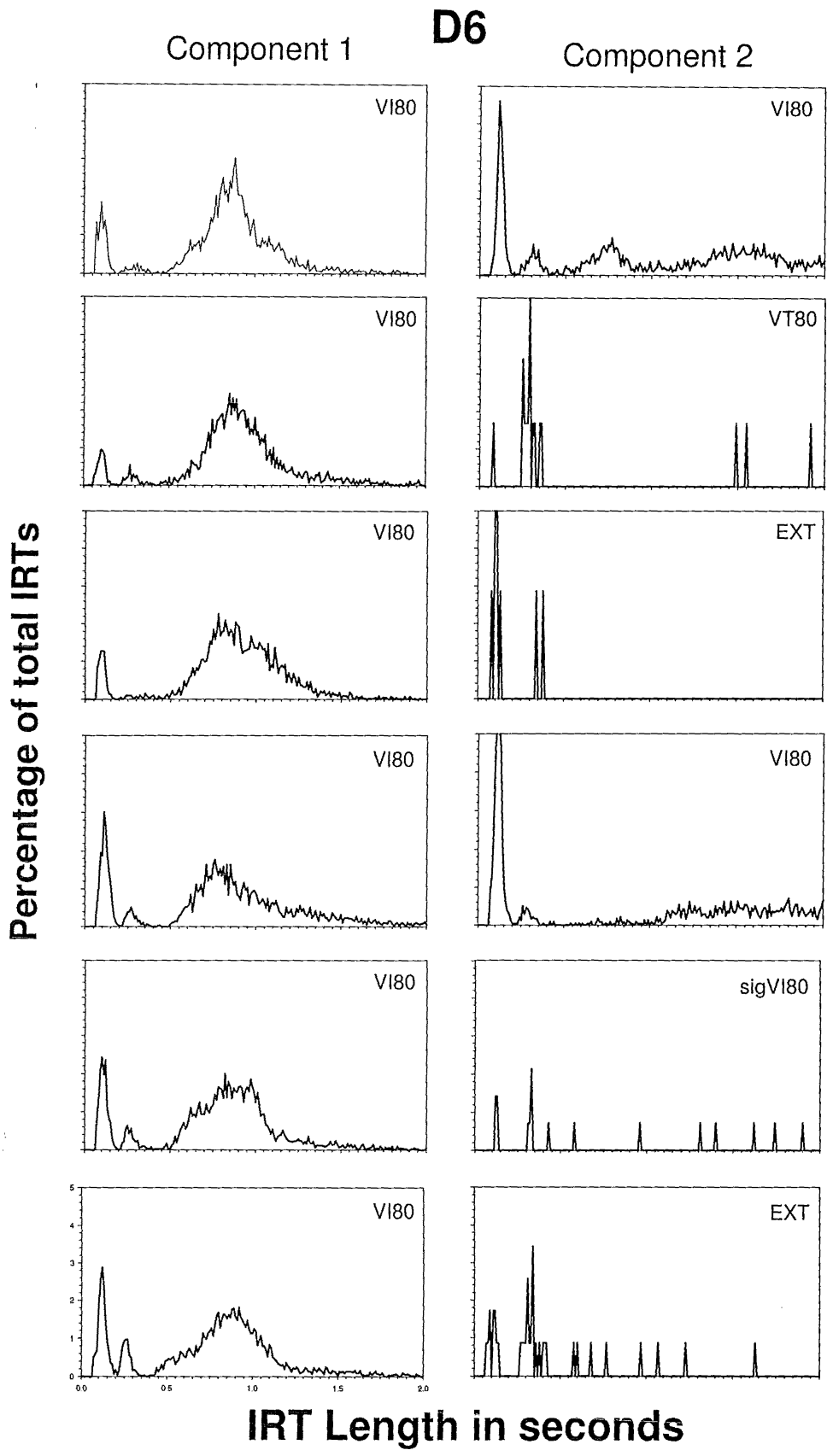

Figure 11b. IRT distributions for the constant component (left column) and the varied component (right column) for bird D6. Each row gives data, averaged from the last three sessions of each condition. The ordinate on each graph shows the percentage of the total number of IRTs (ranging from zero to five percent) with minor ticks at every 0.2 percent. The abscissa on each graph is the length of IRTs and ranges from zero to two seconds with ticks at every 0.05 seconds.

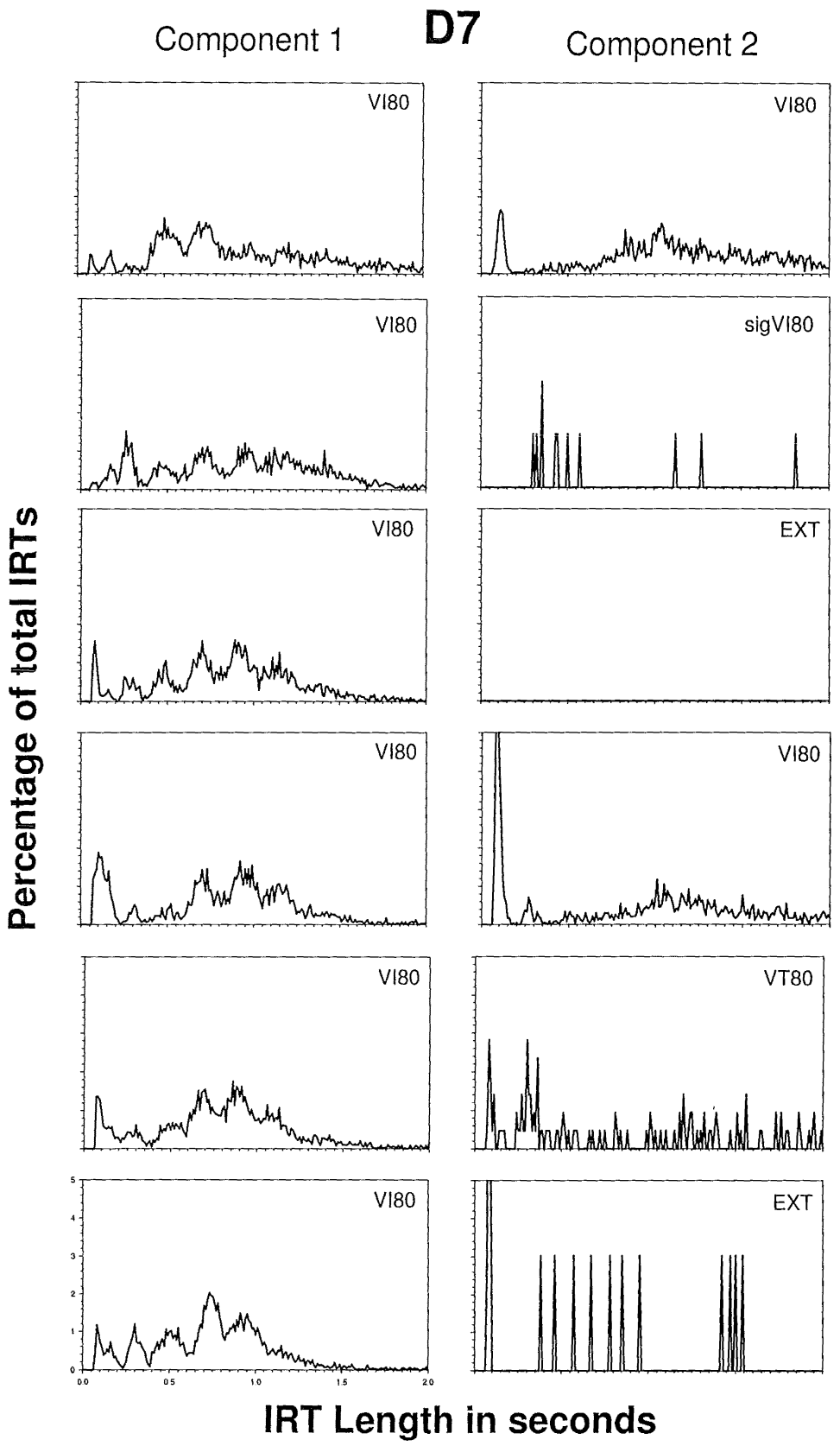

Figure 11c. IRT distributions for the constant component (left column) and the varied component (right column) for bird D7. Each row gives data, averaged from the last three sessions of each condition. The ordinate on each graph shows the percentage of the total number of IRTs (ranging from zero to five percent) with minor ticks at every 0.2 percer The abscissa on each graph is the length of IRTs and ranges from zero to two seconds wit ticks at every 0.05 seconds.

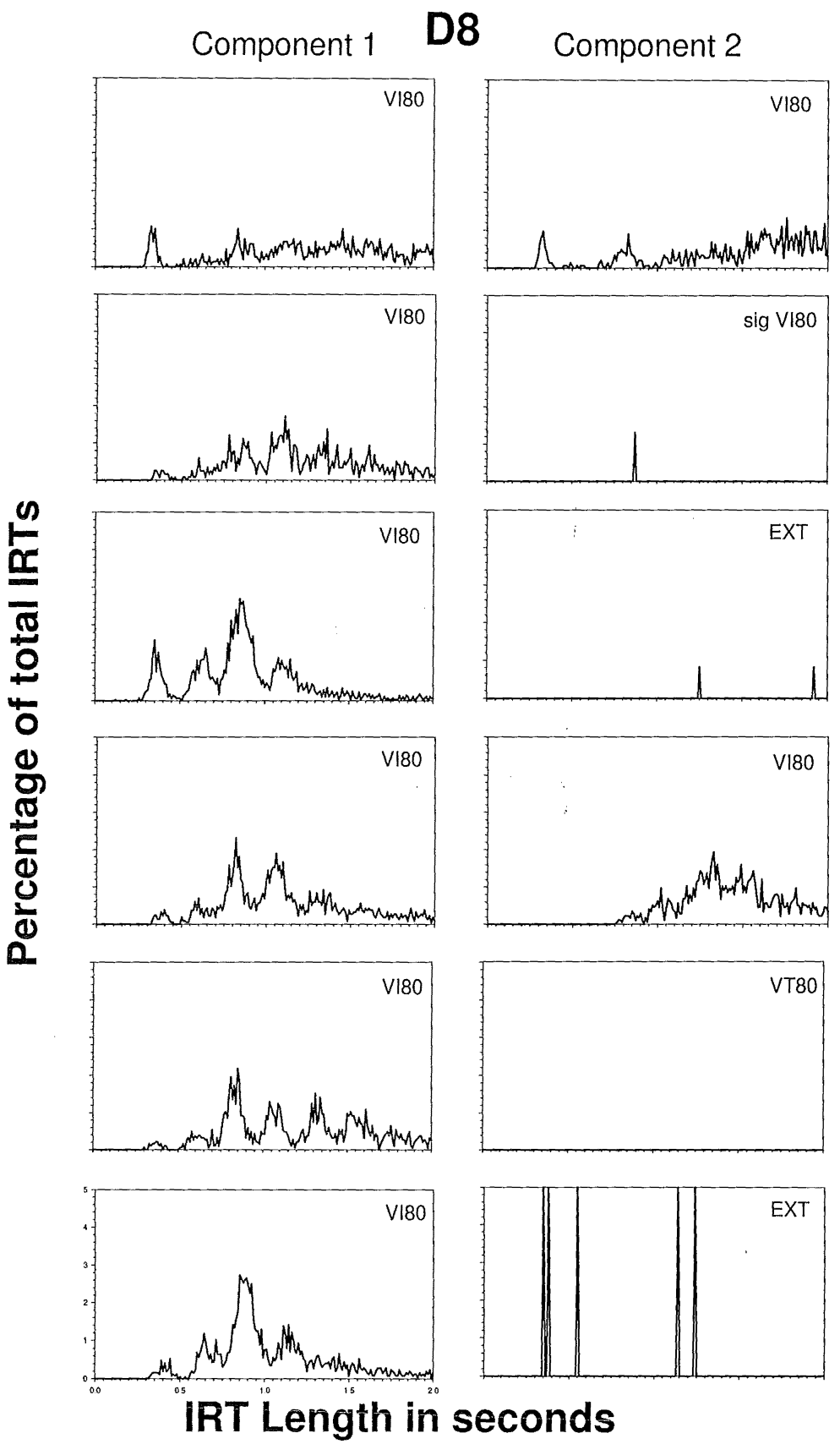

Figure 11d. IRT distributions for the constant component (left column) and the varied component (right column) for bird D8. Each row gives data, averaged from the last three sessions of each condition. The ordinate on each graph shows the percentage of the total number of IRTs (ranging from zero to five percent) with minor ticks at every 0.2 percent. The abscissa on each graph is the length of IRTs and ranges from zero to two seconds with ticks at every 0.05 seconds.

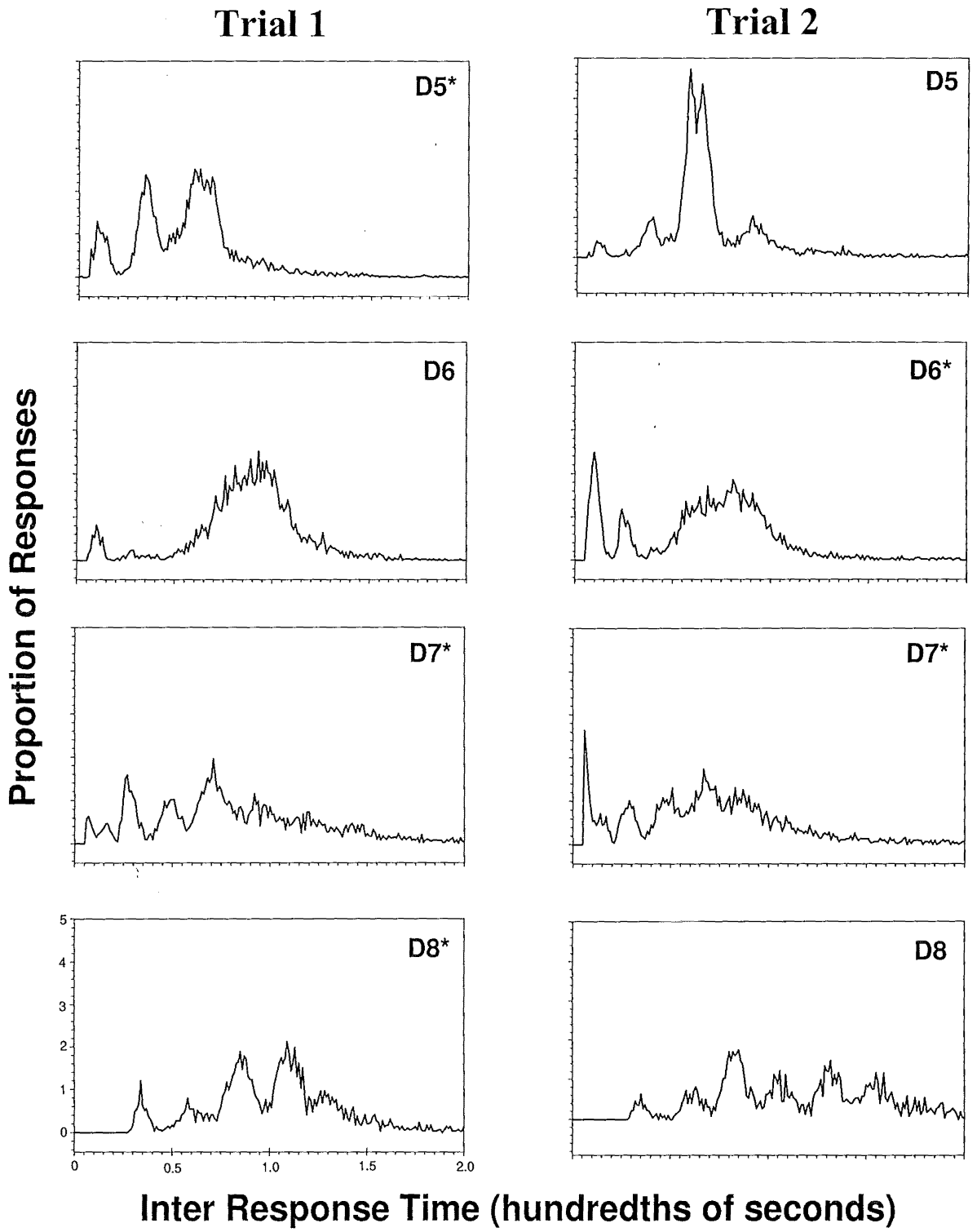

Figure 12: Inter Response Times for responding in the Contant Component in the first three session of extinction during the first two trials (that is extinction immediately following the delivery non-contingent reinforcement or non-contingent signals). Transient contrast is signalled by the asterisk on graphs.

Discussion

Summary of Results

Contrast was not reliably produced by the introduction of either VT or signaled VI in the varied component of a multiple schedule. However, reliable contrast was not produced with the introduction of extinction either, although some transient contrast was observed in some animals. Thus the present research is unable to say much about whether the removal of the contingency (VT) or adding a signal to the VI, and the removal of reinforcement are all equally likely to produce contrast in an unchanged component. However the present research can describe the behaviour that occurs under signaled VI and VT conditions, and compare this with behaviour observed in extinction.

Analysis of the videotapes revealed that distinct behaviours did emerge for all animals in the varied components with either the introduction of non-contingent reinforcement, or the addition of a signal to the VI. These behaviours that emerged were generally distinctive among animals however consistent within individuals and would diminish, sometimes disappearing, with the introduction of the extinction component. The most common of these behaviours was strutting along the interface in a consistent regular movement toward both the red key and the active hopper. Similarly strutting along the tin wall, which was adjacent to the varied component's key, was likely to emerge. These disappeared, or diminished at the least, with the change to extinction in all the animals. In extinction, the observed behaviour was primarily orienting away from the interface wall. In addition scratching generally increased in the varied component during extinction, and the behaviour labeled 'frustration' emerged in two of the animals after around half of each session. Thus

non-contingent reinforcement (VT) and non-contingent signals indicating reinforcement (VI sig) supported stereotyped patterns of behaviour that were not supported to the same extent in extinction.

The IRTs confirmed that each animal developed clear response patterns distinguishable by both body motion on the videos and inter response times. No shifts in inter response time peaks were observed in the constant component with contingency changes in the varied component. Given that no contrast was observed, this result was not surprising. The exception is with the slight transient contrast where the IRT's at that time showed increasing proportions of short IRT's, particularly around 0.3 seconds. There was no evidence of any systematic changes in mode location for any of the animals.

Implications for Theory

As mentioned the experiment failed to produce reliable stable contrast throughout the conditions. This result was not unexpected with the change to VT or signaled VI since results in this area of research, although controversial with signaled VI, have failed to produce contrast in the past. However the subsequent change to extinction has produced reliable contrast in many previous studies (see Halliday and Boakes; 1974). In addition the animals also failed to produce stable contrast with the direct change from mult VI VI to mult VI EXT, a change which produces the clearest contrast in other studies. As mentioned in the introduction, the failure to observe the expected results can indicate inadequacies on the part of the experimental design.

In the current research the animals were given a number of sessions to become familiar with the multiple VI VI that was initiated for baseline. Following this the procedure of 15 session in each of mult VI VI, mult VI VT (or Visig), and

mult VI EXT was repeated three times, with the results from the first being discarded due to inconsistent responding. Following this a final change from a mult VI VI to mult VI EXT was used to give the animals one last chance to demonstrate contrast. Thus the animals were given ample opportunity to produce contrast throughout the experiment, which ran for approximately 200 sessions. Failure to produce contrast with the final change does suggest that the animals may have been insensitive to manipulations of reinforcement in the experiment. However given that the animals did produce response rate fluctuations in the varied component that were consistent with the altered reinforcement conditions, and the fact that in some cases contrast was produced (despite being transient in most cases) this possibility seems unlikely.

Given the novel nature of the research it is worthwhile considering one other explanation for the failure to produce contrast. The current experiment employed a two hopper operant chamber, with each of the components in the multiple schedule operating both a different key and a different hopper. Earlier research into contrast has employed a multiple schedule where both components are reinforced via food distributed through a centrally located hopper, often with only the one response key active and illuminated by different colours to signal different components. Thus the current procedure employed different stimulus colours, different keys, and different hoppers distinguishing between the two components that were operating. It may be that this procedure resulted in diminishing what ever it is that causes contrast to occur in the two component multiple schedule.

Clearly further research would be needed to explore this possibility. Another possible explanation for the failure to observe contrast is the requirements of lighting the room that the videoing imposed. Again this is a variable that has not been explored with regard to contrast however it seems plausible that increasing light

levels will provide increasing amounts of distraction by outside stimulation. This seems especially plausible given the glass enclosure the animals were in during the sessions. However this is not entirely consistent with overall response rates in the current procedure which, although lower than some other studies at between 40-90 responses per minute, were in the range (all be it at the lower end) of general rates observed in a multiple schedule (Williams, 1983).

Taking the current results from the experiment the main finding was that contrast was not produced following the addition of non-contingent reinforcement or non-contingent reinforcement signals. Relating this back to the theories of contrast then there are two possibilities for the contrast theories discussed earlier. The first is that relative reinforcement is the primary vehicle in the production of contrast. Since relative reinforcement does not change when reinforcement is made non-contingent, provided it is matched to previous reinforcement levels, contrast will not be produced. The competition theories have implied that contrast would be produced if the animal's behaviour in the non-contingent condition, was reinforced by extraneous reinforcers, but not if it was maintained by the experimentally provided reinforcement.

Because the response rates in the varied component did show the rapid decreases expected when the VT and signaled VI conditions were introduced, if contrast is to be a result of competition within a component then these conditions must produce and maintain behaviours of their own that are just as rigorous in engaging the animals time. The logic of the present study is that if these behaviours are maintained by food reinforcement (as opposed to R_0) they will disappear with the introduction of extinction. Although contrast was not produced, the main question of

what these animals do in these different contingencies is still valid and provides useful information for the contrast debate.

If the behaviours that occurred in the non-contingent (or signal) conditions were the same as those that occur in the extinction conditions then this would provide unequivocal disconfirmatory support against the competition theories. Williams and Wixted (1994) alluded to this in their article claiming that just as in the extinction component, in the VT component the animal is free to engage in other activities and that this should consume, and effect reallocation of, extraneous reinforcers. McLean (1995) has also written that if pecking is replaced by another behaviour that is demonstrably maintained by food reinforcers reallocation would not be expected and contrast would not occur. The reverse of this therefore must also hold; if observed behaviour in VT and VI (sig) is the same as in extinction, then contrast should emerge with all of these manipulations.

The result of the analysis of the videos clearly showed that new behaviours emerged when responding decreased following the introduction of non-contingent (or non-contingent signal) reinforcement. This behaviour comprised strutting along the interface remaining oriented with head up, bopping around the active hopper, and strutting along the tin. These behaviours are all similar in that they each involve repetitive movement around the hopper or key. The interface panel remained visible to the animal during these activities. Time spent away from the interface panel did generally increase with the addition of non-contingent reinforcement however, with the exception of D8 did not dominate the animals time during this period. However during extinction time spent away from the interface panel continued to increase, often becoming the primary behaviour in the component and often involved orienting directly away from the panel, that is out the back door, a behaviour rarely seen in VT

or VI sig conditions. The behaviours of strutting the interface and tin, and bopping the hopper disappeared, or at least diminished, with the change to extinction. This furthers the support for these behaviours being maintained by the delivery of the non-contingent reinforcement or the appearance of reinforcement signals, and not by extraneous reinforcers.

Thus the analysis of the videos demonstrates that there is a fundamental difference between behaviours exhibited during non-contingent reinforcement, and non-contingent signals, and behaviours exhibited during extinction. This difference is due to the animal spending large amounts of its time around the place of reinforcement, that is the interface panel, in anticipation of the delivery of food reinforcement. The animal has learned that delivery of reinforcement does not occur in extinction conditions, regardless of activities, thus the animal spends more time away from the interface.

What Maintains Terminal behaviours in Extinction

In this paper I have taken the position that non-contingent reinforcement produces and maintains certain behaviours in the operant chamber. In specific the behaviours observed included strutting the interface and the tin wall, and bopping around both the active and inactive hopper. However it is clearly apparent from Figure 10 that these behaviours do not disappear when the non-contingent reinforcement (or signaled reinforcement) becomes extinction. While all show some downturn in the amount of the animal's time they occupy, most stay present to varying degrees throughout the extinction condition. This does appear to be inconsistent with the above argument since the reinforcement is gone and yet the behaviours are still maintained.

The first thing to mention is that while the behaviour categories did remain in extinction some of the specific behaviours in these categories did change. For example D5 spent a proportion of its time bopping the red hopper in the non-contingent reinforcement conditions. While this bopping remained in the extinction condition it did occur more around the green hopper. However clearly some of these 'terminal' behaviours did remain with the change to extinction.

While the animal may have learnt that reinforcement will not be delivered when the varied component stimulus is active, reinforcement is still being provided intermittently during the green (constant) component. Thus the arrival of the green stimulus has certain reinforcing properties in that it signals that the animal now has a chance of receiving reinforcement. For this reason the animal may still exhibit some behaviour that is associated with these food reinforcers. These behaviours remain present but at a level less than when the food could be available at any moment (as is the case if they are responding in the green component or in the non-contingent reinforcement condition). Thus these behaviours may come under some type of temporal control with the fixed arrival of the green stimulus being somewhat predictable.

Terminal Behaviours in Different Contingencies

William's and Wixted (1994) seem to imply that key pecking is the only terminal behaviour in the operant box since they imply that a decrease in key pecking is associated with an increase in 'other' behaviour similar to the 'other' behaviour seen in extinction. However it appears apparent to this author that terminal behaviour in the operant box is not limited to the traditional key peck. In addition to the sensory and motor apparatus that an organism has, it also brings to a situation

what Seligman (1972) refers to as associative apparatus that has a long and specialized evolutionary history. This specialization may make certain contingencies easier to learn than others, more generalizable, or easier to forget. Thus in the operant chamber the animal may be 'prepared' by evolution to associate a given response and reinforcer. In Seligman's view we could tell the level of preparedness animals had for certain contingencies by the ease in which they learnt the contingency rules in question. It is clear that pigeons are in some sense prepared to develop the key peck response to receive food reinforcement since the animal is able to learn the response, and the contingencies, with incredible speed and precision in most instances. In addition, pecking is in any instance, a part of the animal's response to food in that they peck to eat. Thus the key peck develops quickly, and since it is associated with immediate delivery of reinforcement (that is no temporal delay between the peck and the reinforcement) the resulting behaviour under the contingency is not very variable. However this raises the question of what happens when the reinforcement loses this contingency, becoming non-contingent on the animals behaviour.

Killeen (1994) has written extensively on the principles of reinforcement in which he has proposed a quantitative gradient of delayed reinforcement, an exponentially weighted moving average given in Equation 9:

$$M_n = \beta\, y_n + (1 - \beta)\, M_{n-1},\ 0 \leq \beta \leq 1, \tag{9}$$

where M_n is the subjects current memory after the n^{th} response, y_n the relevant attribute of the current response, M_{n-1} is the previous memory and beta (β) is the currency parameter, that is the weight in short term memory assigned to the most

recent response. More specifically Killeen's quantitative model of absolute behaviour for interval schedules is as follows:

$$P = \frac{k'' R}{R + \frac{1}{a}} - \frac{R}{\lambda} \qquad (10)$$

In this equation k" represents the asymptotic response rate (as with Herrnstein's equation), a represents the excitatory property of reinforcement, and λ is the measured rate of decay of short-term memory, essentially representing the number of behaviours that are associated with each reinforcer.

While contingent reinforcement follows the key peck immediately, and as such gives the key peck the highest weighting in current memory (thus a beta approaching 1), this may not be adequate to compete with a more prepared response having an intrinsically larger coupling constant (proportion of responses in response trajectory). Killeen (1994) notes that the availability of these responses with larger coupling constants may lead to 'instinctive drift' where a behaviour is maintained despite it being less effective in obtaining reinforcement than another behaviour within the animals repertoire. This phenomenon was introduced into the literature in an aptly titled article 'The Misbehavior of Organisms' (Breland and Breland, 1961). The key peck response though appears to have both preparedness and currency/recency making it an easily learned behaviour. However it is clear from numerous studies that non-contingent reinforcement and non-contingent signals do not maintain the key peck response, as such beta declines rapidly, and clearly the preparedness is not powerful enough to maintain the behaviour. Other gradients that attract possible target responses may be quite attenuated, providing weak competition for paths with more prepared responses. Consider the behaviours that

emerge in the non-contingent reinforcement and non-contingent signal procedures in the current experiment. These behaviours include bopping the hopper and strutting along the interface, and the tin wall adjacent to the active hopper. Consider these as prepared responses when the animal is anticipating the arrival of food. They are not common in the contingent procedure since the key peck response, due to its larger beta, surpasses it. However beta is quite low for all behaviours now, since the repertoire of behaviours engaged in is variable, and the animal can not infer any event that is directly related to the arrival of the reinforcement. Hence behaviours emerging are those that are more prepared to occur around times when food is about to be delivered.

Williams and Wixted (1994) asked the pertinent question as to why these behaviours do not disappear in a way similar to the key peck response when the reinforcement is made non-contingent or is signaled. That is why doesn't the same mechanism as that reducing pecking also reduce these other activities? While this argument may seem quite logical on the surface further consideration of the issue reveals the answer. Firstly, while the reinforcement is no longer contingent on responding it is still present. Prior to the change in conditions the reinforcement motivated the animal to key peck, which they did for very high proportions of their time. The reinforcement is still present, therefore it seems reasonable to assume that this motivating factor is still present, that is the reinforcement is providing motivating for some behaviour. However, the contingency has loosened from the one clear 'terminal' response of pecking, to a host of responses, also terminal, associated with the delivery of the non-contingent reinforcement or the non-contingent signal.

The animal replaces the key peck as the amount of weighting it has in current memory (the beta parameter) diminishes, a process that occurs rapidly since key pecking is often not the event occurring immediately prior to reinforcement. Key pecking levels off at a point in which preparedness results in only very low levels of responding. Other prepared behaviours associated with food emerge, but none are consistent or sustained enough to occur before reinforcement continually (thus become completely associated with the reinforcement) hence behaviour remains variable (yet generally terminal) in the non-contingent procedure. Expand this notion and it becomes apparent, to this author at least, that these prepared responses will be maintained to a lesser extent in the extinction component of a multiple schedule. It would be illogical to view the extinction itself as maintaining terminal behaviour, however extinction is alternating with periods of reinforcement that may do so.

Contingencies have the effect then of steering an organism's behaviour towards terminal responses that are involved in the contingency. Given that the VI contingency is associated with one clear terminal response, that being key pecking, and the VT schedule is associated with no particular terminal response it would seem that pigeons may prefer the VI contingency over the VT contingency as it is easier for them to infer a causal link between their behaviour and the reinforcement. This is despite the VT contingency providing 'free reinforcement' and thereby appearing to be more appealing by the experimenter's point of view. Halliday and Boakes (1972) demonstrated that pigeons do indeed prefer a VI to a VT schedule. They demonstrated this by providing the animals with a concurrent chain procedure used to measure preference (However see Neuringer, 1969, who failed to observe FI over FT preference in similar conditions).

"Othering" in the Operant Chamber

It seems rather clear that what the animal does in the operant chamber can be broken into two categories, namely behaviour maintained by reinforcement provided by the experimenter and behaviour maintained by extraneous reinforcement, not provided by the experimenter but by the setting or the animal itself. The current experiment has demonstrated that the first category can include more than just the standard on task key peck. It can include a host of behaviours that the animal associates with the delivery of reinforcement, thus, due to the probability of reinforcement being high, the anticipation of reinforcement means the animal engages in more behaviour around the hopper or key. Thus the motivation provided by the food reinforcement is not only exhibited in key pecking but in strutting along the interface and in bopping the hopper.

So where does that leave other behaviours in the scheme of things? As discussed in the introduction, Staddon and Simmelhag (1971) have used the term interim behaviour to refer to behaviours that occur in the experimental chamber when the probability of reinforcement is low, as opposed to terminal behaviours when the probability of reinforcement is high. The authors view the interim and terminal behaviours as states dependent on the class of reinforcer available at the time and the applicability of principles of variation appropriate to that class of reinforcer. As such the terminal state corresponds to the terminal reinforcer (food), while the interim state corresponds to all other reinforcers.

Firstly it seems logical to assume that extraneous reinforcers are available to the animal at all times in the operant chamber. Thus behaviour that is engaged in to receive these reinforcers can also occur at all times across components. Staddon and

Simmelhag view a reciprocal relation occurring between interim and terminal states whereby the strength of one state directly effects the strength of another. They write that "activities during the interim period are directly related to the strength of the terminal response" (p.35). It appears that what Staddon and Simmelhag are alluding to as the same type of competition that competition theorists refer to as occurring within individual components, that is the competition between engaging in 'on task' behaviour and engaging in 'other' behaviour. This is also apparent in Herrnsteins original assumption that k, a constant of behaviour, is made up of $B + B_0$.

However the authors in my view confuse the causal direction of the low probability of reinforcement and the interim behaviours. They claim that animals enter this interim state when there is a low probability of reinforcement. It seems likely to this author that there may be certain behaviours that the animal will do across the session regardless of experimental reinforcement. When these behaviours occur may well be related to the probability of reinforcement at the time, but these activities will occur at some time in the session since the animal is to a certain extent predisposed to engage in them by the physiological demands of the operant chamber. For example scratching and grooming are activities that could be argued to be on some type of Variable Interval schedule, which is somewhat richer due to the confined nature of the operant chamber and the monotony of the task of responding. Thus at certain times the animal will generate a desire to itch. The animal can choose to scratch immediately or postpone scratching for some time due to a perceived greater desire to continue with the current behaviour. When the animal decides to scratch may be dependent on the reinforcement conditions, and the subsequent probability of reinforcement, however the behaviour itself was not caused by the low probability of reinforcement. Therefore competition is occurring

throughout components. This has been demonstrated quantitatively using the concurrent reinforcement interaction effect documented by Catania (1963) and Rachlin and Baum (1972).

Thus it seems that other behaviour is not generated by lack of experimental reinforcement, but is engaged in more during these times due to less competition among response alternatives. Clearly this line of thinking sets the stage for behavioural contrast in the two component multiple schedule by either reinforcer reallocation or behavioral competition. In fact matching dictates that the occurrence of other behaviour (B_0) must increase at this time since as the probability of R_1 decreases, the function $R_o / R_1 + R_0$ increases.

Inter Response Time Data. Implications for theory?

Before drawing conclusions from the current research it is worthwhile examining the IRT data gained across the experiment. By examining the animals inter response times, behaviour is being examined on a molecular level. The IRT distributions displayed in figures 11(a-d) show peaks (modes), where responding is more likely at particular times after the last response. Some of these peaks are individual to the animal, such as D6's cluster around 0.9 seconds, however some are more consistent across animals. Palya (1992) demonstrated these concentrations of IRTs at certain lengths that were unchanging across conditions and relatively stable across animals. The first band tended to be located at 0.35 seconds, the others at around 0.7 and 1.2 seconds. Clearly the second and third band are rough multiples of the first band which suggested (to Palya at least) a standard timing mechanism that governs pecking behaviour. Other commentators of IRT distributions have discussed this temporal pattern of responding. Killeen (1994) attempts to predict overall

response rates based on these IRT details referring to the animals maximum response rate, the reciprocal being delta, the minimum inter response time. Killeen argued that the minimum inter response time for both pigeons and rats was around one quarter of a second (Killeen, 1994).

Rau (1997) in an unpublished study examining the molecular structure of multiple schedules examined these IRT patterns in 8 pigeons. The multimodal structure in the IRT range of 0-3 seconds that she observed indicated patterns of responding of a periodic nature, as suggested by Payla, with the first peak at around 0.3 seconds (varying across animals between 0.3 and 0.4 seconds). In addition, as also suggested by Payla, the peak locations did not vary for each animal to a great extent across different conditions. As discussed in the results, this is consistent with the current findings as times when temporal contrast was displayed, IRTs during this period were characterized by a change in existing peak probability, not by increasing time spent engaged in responding.

The peak at 0.1 seconds is something that should not occur since the animal does not have the ability to respond this rapidly. That is an animals minimum inter response time is previous studies is in the vicinity of 0.3 seconds. Modern computers have the ability to record responses down to millieseconds, yet the animal is constrained by physiology to respond any faster. If the animals minimum IRT was only 0.1 seconds its maximum response rate becomes much greater, a rate approaching 360 responses per minute which has never been demonstrated in any schedule or contingency. However only D8 showed no sign of a peak around 0.1 seconds. It is this authors opinion that this is a result of the mechanisms of the chamber being highly sensitive to touch.

The timing resolution of the interface was dropped to one-hundredths of seconds in order to record highly accurate IRTs. In doing so it allowed electrical feedback to be recorded as pecks. Other explanations for these short IRTs are that the animal pecks the key with an open mouth, thus creating two impacts on the key from the top and bottom beak. If the equipment is sensitive enough then this latter peck will register as a separate response altogether. Or the peak could also be due to key bounce effect in the experimental chamber. That is a response at the right intensity may cause the key to rebound off the interface thus in actuality registering two responses. Which of these alternative explanations is responsible for the current 0.1 second peak is unclear, however it is highly likely that one of the above provides the explanation.

The results of the IRT examination are seriously limited by the failure to observe stable contrast however they do hint at an explanation that seems inconsistent with competition theorists accounts of contrast. When transient contrast was observed the analysis of the IRTs suggested that increases in the proportion of rapid responses (particularly around 0.3 seconds) were responsible for the effect. This suggests that rather than spending more of its time pecking (since it doesn't have to spend its time collecting extraneous reinforcers); the animal is spending the same amount of time at the key, only it is responding more rapidly. That is, change in conditions results in animals responding more rapidly than before, not spending more of its time responding. Therefore the number of responses elicited by a given incentive (specific activation, *a,* in Killeen's model) has increased meaning the motivational conditions must be increasing towards there optimum.

Towards a Conclusion

Williams and Wixted (1994) presented a critique of the competition theories of contrast concluding the empirical evidence supporting them was weak. The essence of their criticisms centered on two aspects of the evidence. Firstly they presented a fit of their 1986 model to McLean's (1992) data on reallocation and contrast discussed earlier. They argued that the reanalysis of this data revealed that there was an effect of reinforcement in the alternative component of the schedule independent of the shifts in reinforcers between components. In addition they argued, as also mentioned earlier, that the non-contingent reinforcement procedure and the non-contingent signal procedure provided damning evidence against competition theories since these produced rapid declines in responding in the varied component while failing to produce contrast in the constant component. While Williams and Wixted did not dismiss reallocation entirely, since contrast may result from several different mechanisms, they did conclude that behavioural competition was "a poor candidate for an explanation of any significant amount of the contrast effect" (P.110).

McLean (1995) in a further paper examining reallocation of extraneous (extra key) reinforcers revealed logical problems with the first of these arguments. While the fits that were obtained by Williams and Wixted's (1986) model were impressive they incorporated a term, in this latest use, taking account of the reinforcement from the extra key. That is, in reality they incorporated the reallocation itself into the equation, this reallocation that was never part of their original model. Of the two parameters used in the model, parameter *a* had a greater value than *b* indicating that a greater part of the contrast observed could be accounted for by changes in extra key reinforcement (that is, by reallocation) in that component than by reinforcement rate

in the varied component. Clearly this rebuttal is sufficient to dispel the first of the criticisms presented in the Williams and Wixted (1994) article.

The current research was an examination of the second of these criticisms. As analyzed in the introduction, the essence of the argument is dependent on the behaviours the animal engages in each of the conditions, that is VI, VT, VI (sig), and EXT. Taking it that contrast is not produced by the introduction of non-contingent reinforcement (or non-contingent signals), which unfortunately the current research has little to contribute, if behaviour in the variable time or signaled variable interval is similar to behaviour in the extinction condition behavioural competition theorists are forced to conclude that contrast should occur. Since previous research suggests contrast does not occur with non-contingent procedures especially, this would dispel competition accounts of behavioural contrast to a large degree. While the current procedure failed to produce contrast it seems reasonable to assume that behaviour in the chamber was consistent with behaviour in other chambers under the same conditions. That is the behavioural analysis of the animals in the different conditions is still valid data.

These results showed clearly that the behaviours that emerged during non-contingent reinforcement and non-contingent signal, procedures were distinct from the behaviours that emerge during extinction. The characteristic difference was that during the VT and VI (sig) procedures the animals stayed oriented towards the interface panel moving along the front, or bopping around the hopper. In contrast extinction was characterized by behaviour oriented away from the interface, although the above behaviours did occur to some extent. Large proportions of this time spent away from the interface involved standing looking out the back window and grooming. In addition 2 of the 4 animals developed behaviours labeled frustration,

due to the visible signs of aggravation that developed in these animals towards the end of the extinction sessions.

Therefore although behavioural contrast is not produced using the non-contingent procedure (or non-contingent signals), the current experiment provides competition theorists with empirical validation of their explanation of this lack of contrast. That is the production of reinforcement dependent behaviours, that replace the key peck, and limit the amount of reallocation that can occur in the VT procedure. Due to the lack of opportunity for reallocation, contrast can not occur by competition theorists accounts.

In the same article in which McLean dealt conclusively with the first of Williams and Wixted's (1994) criticisms of Competition (McLean, 1995), he also presented an argument for the rejection of behavioural competition theorists accounts of contrast. The reasoning came down to firstly behavioral competition theory being contrary to McLean's conclusion of successive independence, since changes in the distribution of behaviour between pecking the response key and engaging in other behaviour would, if unrelated to changes in reinforcement in that component, be contrary to the conclusion of successive independence. Secondly behavioral competition theories were, McLean argued, inconsistent in accounting for the changes in absolute response rates in the constant component. If reductions in responding on the main key, following increases in reinforcement in the varied component of data presented by McLean, 1995, were due to behavioural competition, then increases in response rate on the extra key in the constant component would be expected. On the whole, this did not occur as contrast effects on the main key often occurred in the absence of changes in response rate on the extra key, see McLean 1995.

Competition then, in the form of reallocation of extraneous reinforcers, is not challenged by Williams and Wixted's critique's, and seems to provide a better account of the available data than behavioral competition. McLean has provided numerous amounts of supportive evidence for the theory thus for the moment it seems reasonable to conclude that a large portion of the behavioural contrast effect is due to the reallocation of extraneous reinforcers.

Future Areas for Examining the Contrast Debate

While the tenuous conclusion presented here is that reinforcer reallocation may account for a significant portion of the total contrast effect reported so widely, this is tempered by other areas, still under reported, which provide conflicting results for accounts of contrast from theories of competition.

The first concerns the results Williams (1981) reported examining the three component multiple schedule where contrast effects were more prominent in the component that immediately preceded the varied component than the one that immediately followed it. That is, contrast appears from this line of research, to be anticipatory in nature. If it is the case that contrast is anticipatory in nature, a result which at this point has not been replicated sufficiently by independent authors, then anticipation, rather than competition or reallocation, may provide the mechanism by which contrast occurs. However these findings were tempered by additional local contrast data from the same study suggesting contrast effects in the first portion of a component following the varied component were the most significant. The amount of the overall contrast effect that is made up by local contrast has yet to be adequately quantitatively validated.

Another line of research, which is only recently emerging, also challenges competition theories. Inter response time data suggest contrast is the result of an increasing proportion of more rapid pecks and not changes in the basic tempo of responding. This, as alluded to in Rau (1997), is inconsistent with reallocation theory accounts of contrast however needs to be examined in more depth before its influence on theories can be examined comprehensively.

Finally, observing the animal in the operant chamber opens up numerous avenues for future research into a host of operant psychology phenomena. What the animal actually does in the chamber has proven in the past to be somewhat allusive yet its importance has never been questioned. While methods for examining actual behaviours in the chamber are still only in their infancy, and the reliability can clearly be questioned, many areas, including the contrast debate, will benefit in future years from this line of research. The reason for this is that what the animal actually does is so central to all theories of any phenomena in the operant chamber.

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Appendix A

The reliability of the measures of coding the videotapes was assessed by inter rater reliability. A postgraduate student, familiar with the area of operant psychology, was paid to code some of the tapes for the purpose of reliability checks. This student was provided with no guidance as to behaviour categories, or what the nature of the study was. She was informed that the requirements were to categorize the animal's time in the chamber into several different behaviours providing both an explanation of each behaviour, and the amount of time the animal spent engaged in this activity. Due to the nature of the requirements of the study, and time and financial constraints, rather than doing random pigeons in random conditions, one animal (D5) was followed through both trials being rated a second time for one session in each condition, thus six sessions altogether. In addition, as only activities in the varied component were considered in the results, only red key behaviour was categorized.

This student came up with the following categories of behaviour.

- Pecking red key
- Facing front, head sweeping diagonally down to the right
- Grooming
- Head in Red Hopper
- Head movement up and down
- Pecking at floor
- Front of chamber pacing left and right
- Turning in circles
- Wing Flapping
- Standing away from key

The initial definitions of behaviour categories used was:

Key pecking on active key: Animal is oriented to key and is involved in repetitive, continuous responding on the active key.

Time to start responding: Following Multiple Schedule changes, the time it takes the animal to produce its first response

Post reinforcement Pause: Following reinforcement, the time it takes the animal to produce its next response.

Bopping on active hopper: Orienting to key but not responding, rather moving head in repetitive manner between active key and hopper.

Bopping on other key/hopper: Not responding, moving head in repetitive manner between active key and inactive key or hopper.

Strutting interface wall: Not responding, moving entire body in repetitive movements along the interface wall

Strutting metal wall: Not responding, moving entire body in repetitive movements along adjacent metal wall.

Not orienting to interface wall: Facing away from the interface wall, however not engaged in repetitive movements.

Scratching: consists of; *Wingflapping*: Animal extending its wings and flapping them, *Grooming*: Scratching own body with either its claw or beak, and *Grill Pecking*: Pecking at the grill mesh floor.

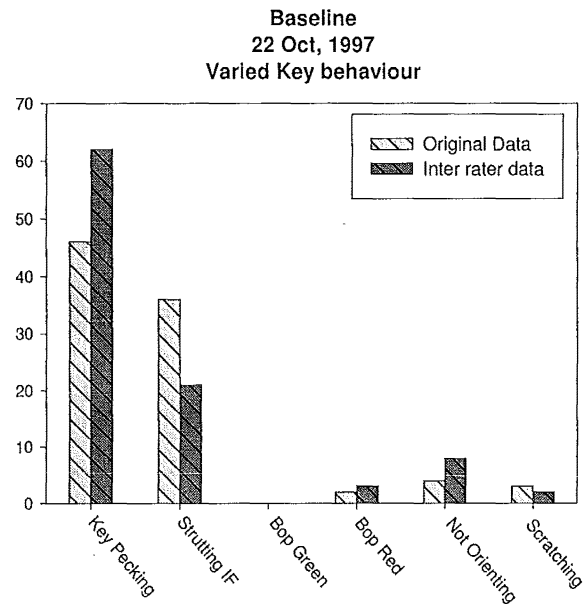
Frustration: Rapid boping, wingflapping and jumping at back window in frustrated manner.

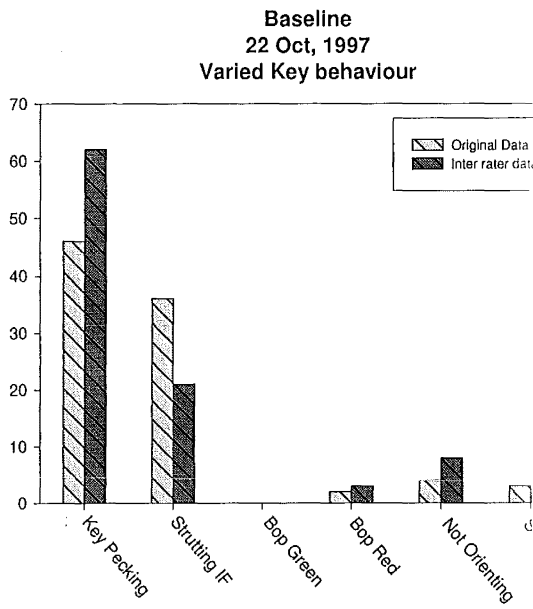
With the exclusion of strutting long the tin wall the main behaviours are clearly captured by this system in a way similar to the initial categories. That is pecking red key is clearly the same in both categories. Facing front, head sweeping diagonally down to the right clearly corresponds with bopping the inactive hopper. Grooming, pecking at floor and wing flapping were all collapsed into the one category (as in the first instance). Head in red hopper and head movement up and down clearly relate to bopping the active hopper. Front of chamber pacing left and right is clearly strutting the interface. Finally standing away from key and turning in circles, which was initially used however later collapsed in the initial categories is similar to orienting away from the interface. The other behaviour that did not occur in the second categorization was frustration, however considering that animal D5 did not demonstrate frustration by the initial analysis this is consistent with the original results. Other aspects of the initial categories that did not

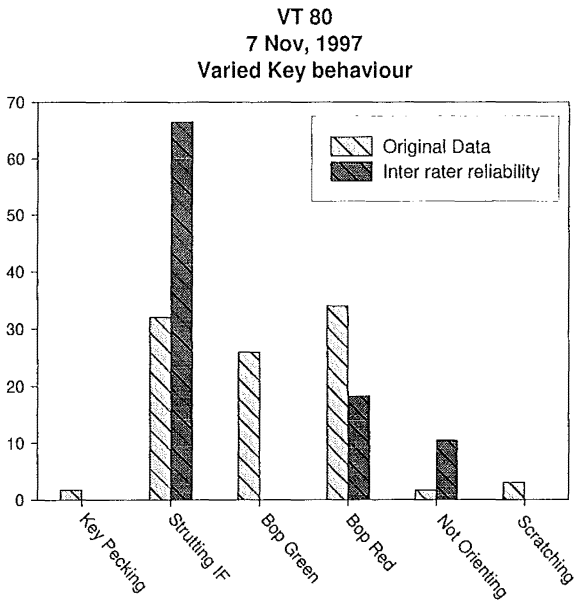
appear were the categories time to start, and post reinforcement pause. Given that these are more specific to behavioural incidents, investigated to examine specific questions which did not prove valid upon examination, this is not surprising either.

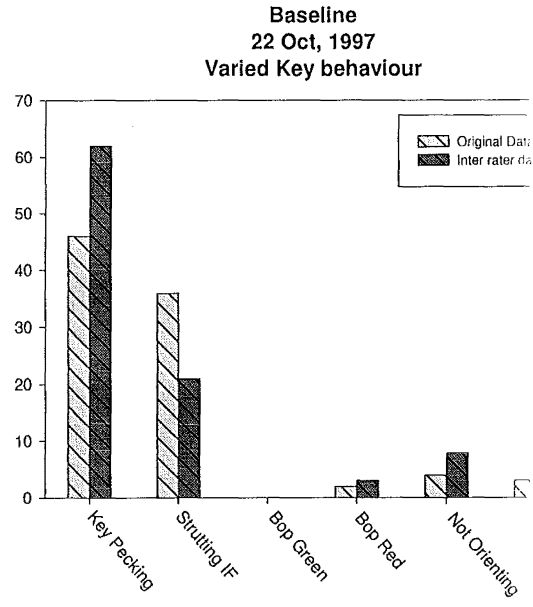
Graphs of the corresponding portions of time allocated to different behaviours are presented. Note that there are some substantial differences between the experimenter's classifications of the animal's time and the later examination by an independent observer. These inter rater checks do demonstrate the difficulty of labeling the animals behaviour with a consistent method.

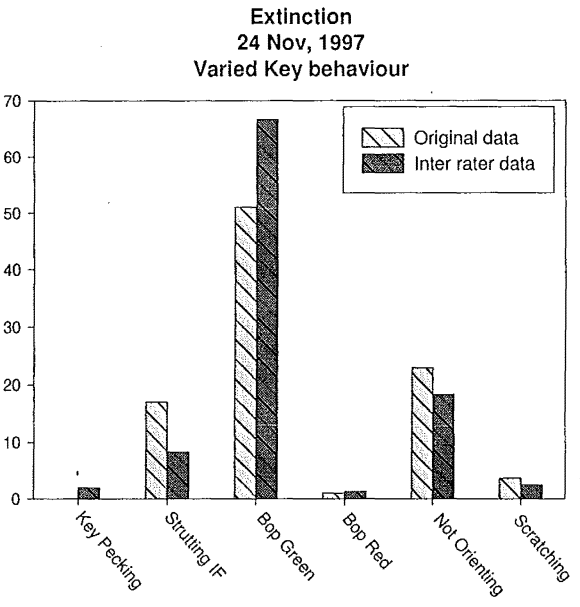
One aspect of the categories that may account for some of the discrepancies occurs with slightly different definitions of behaviours. For example on the 7th of November tape D5 was in the signaled VI 80 condition. The initial coding had the animal primarily engaging in strutting along the interface and bopping the green hopper. The second coding had the animal mostly strutting however the definition of strutting had changed for this condition to "Front of chamber pacing left and right with diagonal head movements down to the right" (the green hopper), thus a combination of the two categories. In addition, while the discrepancies do seem quite damning to the current work its effect on the findings is limited at any rate since using the second ratings the same conclusions are drawn. That is there is clear evidence that during contingent reinforcement key pecking is a dominant behaviour. During non-contingent reinforcement time spent key pecking diminishes and other behaviours arise, such as strutting and bopping, orienting away from the interface remains low in with this contingency. And subsequently with the addition of extinction time spent orienting away from the interface increases.

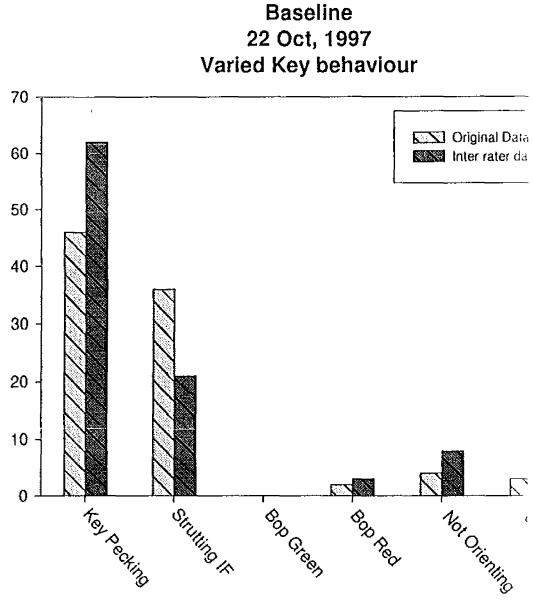












Appendix A: Graph showing portion of time spent engaged in different behaviours during different conditions by both raters.

Appendix B

Table 1: Average absolute response rates, from first and last five sessions, presented in responses per minute for all animals during both trials. Standard Deviations are provided in brackets. Component C is the constant component (VI 80 throughout) and V is the varied component (component values given).

BIRD	COMPT	Schedule in varied component and responding in either component						
		VI80	VT80		EXT		VI80	
		Last 5	First 5	Last 5	First 5	Last 5	First 5	Last 5
		Mean(SD)	Mean(SD)	Mean(SD)	Mean(SD)	Mean(SD)	Mean(SD)	Mean(SD)
D5	C	77.0 (9.6)	85.6 (3.4)	82.0 (3.2)	100.0 (7.2)	84.4 (10.3)	79.4 (4.2)	76.2 (6.6)
	V	70.8 (5.7)	38.6 (18.0)	6.0 (5.4)	16.5 (11.0)	6.5 (9.3)	75.6 (16.8)	63.2 (4.1)
D6	C	68.1 (1.8)	65.0 (2.4)	56.7 (7.1)	66.1 (4.0)	66.6 (4.9)	64.1 (8.5)	65.0 (2.6)
	V	44.6 (5.6)	25.0 (14.2)	1.0 (0.8)	3.9 (5.9)	1.2 (1.0)	25.1 (15.0)	44.8 (6.8)
D7	C	56.0 (5.7)	59.7 (6.4)	66.1 (3.3)	74.8 (6.4)	51.4 (9.1)	52.1 (13)	63.2 (3.1)
	V	37.4 (5.7)	15.1 (10.3)	2.9 (1.7)	8.6 (6.0)	1.7 (0.5)	37.2 (9.2)	40.6 (11.9)
D8	C	37.2 (6.7)	30.8 (8.9)	34.3 (13.1)	34.3 (6.8)	45.2 (6.8)	41.2 (7.8)	24.1 (8.2)
	V	27.3 (4.2)	14.0 (11.9)	1.2 (1.2)	1.3 (1.7)	0 (0)	17.9 (16.4)	36 (6.2)

BIRD	COMPT	Schedule in varied component and responding in either component						
		VI80	sigVI80		EXT		VI80	
		Last 5	First 5	Last 5	First 5	Last 5	First 5	Last 5
		Mean(SD)	Mean(SD)	Mean(SD)	Mean(SD)	Mean(SD)	Mean (SD)	Mean(SD)
D5	C	76.2 (6.6)	78.9 (4.0)	78.1 (4.6)	79.6 (6.1)	81.8 (3.3)	80 (4.3)	78.1 (4.2)
	V	63.2 (4.1)	29.8 (19.6)	31.3 (6.9)	30.5 (3.2)	42.1 (8.1)	72.9 (14.4)	70.4 (4.5)
D6	C	65.0 (2.6)	72.0 (3.6)	71.8 (3.5)	80.8 (2.1)	82.1 (5.2)	72.2 (1.5)	66.8 (3.4)
	V	44.8 (6.8)	21.1 (17.6)	3.2 (1.4)	15.6 (7.8)	33.5 (25.9)	68.5 (6.5)	63.2 (1.9)
D7	C	51.7 (2.0)	59.9 (2.6)	53.8 (1.2)	67.5 (2.9)	57.0 (3.7)	51.3 (8.7)	56.0 (5.7)
	V	40.9 (4.3)	15.8 (11.8)	1.6 (1.2)	6.2 (8.5)	0.1 (0.1)	25.0 (12.4)	37.4 (5.7)
D8	C	22.7 (6.7)	25.2 (2.2)	26.7 (10.6)	43.2 (15.6)	47.2 (9.2)	37.3 (1.5)	37.2 (6.7)
	V	20.9 (7.5)	11.8 (5.5)	2.2 (1.2)	2.6 (1.4)	2.4 (1.3)	2.8 (5.5)	27.3 (4.2)

Appendix C

Table 1: Percentage of time D5 spent engaged in behaviours during the last three sessions of each condition. Component 1 is the constant (green key) component component 2 is the varied (red key) component. Standard deviations across the three sessions averaged is presented in the brackets. Description of each behaviour is presented in the method.

D5		Categories									
		1	2	3	4	5	6	7	8	9	10
VI-VI	Cmp 1	78.9 (4.9)	7 (0.6)	2.7 (0.4)	9 (4.9)	1.2 (0.6)	1.2 (0.2)	0.1 (0.1)	0	0	0
	Cmp 2	57.2 (10)	3.6 (0.7)	3.5 (1.4)	0.9 (1.5)	2.3 (1.8)	1 (1.2)	31.3 (5.2)	0	0	0
VI-VT	Cmp 1	92 (0.4)	3.5 (0.8)	1.5 (0.2)	1.5 (1.4)	1 (1)	0.6 (0.2)	0 (0)	0	0	0
	Cmp 2	1.3 (0.8)	0	0	61.5 (8.1)	2.1 (0.4)	2.6 (0.5)	18.6 (6.3)	14 (13.2)	0	0
VI-EXT	Cmp 1	94 (1.1)	2.8 (1)	2.2 (0.5)	0.3 (0.6)	1 (0.2)	0	0	0	0	0
	Cmp 2	0.2 (0.2)	0	0	1.5 (0.6)	27.2 (3.9)	6.4 (3.3)	43.3 (4.9)	18.2 (2.6)	0	0
VI-VI	Cmp 1	88.1 (2.7)	3.5 (0.5)	2.6 (0.4)	0.4 (0.6)	4.4 (1.1)	0.7 (0.1)	0.4 (0.5)		0	0
	Cmp 2	75.5 (4.0)	3.7 (0.5)	3.1 (0.4)	0.2 (0.2)	7.5 (2.8)	2.1 (0.4)	2.0 (0.5)	6.0 (0.9)	0	0
VI-sigVI	Cmp 1	88.4 (0.8)	5.1 (0.6)	2.3 (1.0)	0.9 (0.7)	1.1 (0.9)	0.4 (0.3)	1.9 (0.8)		0	0
	Cmp 2	71.3 (8.1)	3.2 (0.2)	3.5 (0.2)	0.4 (0.6)	0.1 (0.2)	5.4 (7.2)	3.8 (5.6)	12.1 (1.6)	0.0	0
VI-EXT	Cmp 1	91.3 (3.1)	3.7 (1.8)	3.6 (0.5)	1.1 (0.8)	0.3 (0.3)	0.0	0.0	0.0	0.00	0
	Cmp 2	7.1 (6.3)	0.0	0.0	3.9 (1.5)	17.1 (9.6)	3.4 (0.2)	45.6 (8.8)	20.1 (14.1)	2.9 (2.1)	0.0

Behaviour Key

1: Key Pecking
2: Time to start
3: Post reinforcement pause
4: Bopping on Hopper
5: Not orienting
6: Scratching
7: Strutting interface
8: Bopping inactive hopper
9: Strutting tin
10: Frustration

Appendix C

Table 2: Percentage of time D6 spent engaged in behaviours during the last three sessions of each condition. Component 1 is the constant (green key) component component 2 is the varied (red key) component. Standard deviations across the three sessions averaged is presented in the brackets. Description of each behaviour is presented in the method.

D6		Categories									
		1	2	3	4	5	6	7	8	9	10
VI-VI	Cmp 1	89.5 (0.7)	2.3 (0.2)	3.3 (0.6)	1.2 (1.1)	2.4 (0.3)	0	1.2 (0.2)	0	0	0
	Cmp 2	54.9 (5.4)	3.4 (0.4)	3.5 (0.4)	0	6.7 (3.2)	1.5 (0.3)	30.1 (3.4)	0	0	0
VI-VT	Cmp 1	81.8 (1.7)	2.8 (0.1)	4.3 (1.3)	0.4 (0.4)	3.6 (1.2)	2.1 (1.7)	5.1 (2.6)	0	0	0
	Cmp 2	0 (0)	0	0	6 (4.7)	9.4 (3.5)	1.5 (0.8)	83.1 (7.9)	0.1 (0.1)	0	0
VI-EXT	Cmp 1	88 (1.5)	2.5 (0.7)	2.7 (0.4)	0	0.4 (0.5)	0.3 (0.3)	6.6 (1.5)	0	0	0
	Cmp 2	0	0	0	0	32.8 (6)	9 (5.5)	34.8 (18.1)	0.1 (0.1)	22.2 (10.9)	0
VI-VI	Cmp 1	86.2 (2.0)	3.6 (0.6)	2.5 (0.3)	3.2 (1.9)	2.2 (0.7)	1.0 (0.4)	1.3 (0.2)	0	0	0
	Cmp 2	60.9 (3.8)	5.0 (0.2)	2.3 (0.4)	0.1 (0.1)	21.7 (2.0)	2.1 (1.3)	3.3 (1.4)	4.2 (2.5)	0	0
VI-sigVI	Cmp 1	88.2 (2.9)	2.7 (0.4)	3.2 (0.3)	0.7 (0.7)	3.9 (1.5)	0.4 (0.2)	0.7 (0.6)	0.7 (0.7)	0	0
	Cmp 2	8.7 (1.2)	0.0	0.0	1.0 (0.2)	14.5 (3.6)	2.3 (0.3)	67.3 (3.2)	6.3 (1.2)	0	0
VI-EXT	Cmp 1	91.7 (1.2)	2.3 (0.1)	5.4 (1.3)	0.6 (0.1)	0 (0.1)	0.0	0.0	0.0	0	0
	Cmp 2	2.1 (0.4)	0.0	0.0	1.6 (0.0)	16.3 (5.5)	11.2 (11.6)	60.5 (16.1)	3.8 (2.8)	4.4 (1.4)	0

Behaviour Key

1: Key Pecking
2: Time to start
3: Post reinforcement pause
4: Bopping on Hopper
5: Not orienting
6: Scratching
7: Strutting interface
8: Bopping inactive hopper
9: Strutting tin
10: Frustration

Appendix C

Table 3: Percentage of time D7 spent engaged in behaviours during the last three sessions of each condition. Component 1 is the constant (green key) component, component 2 is the varied (red key) component. Standard deviations across the three sessions averaged is presented in the brackets. Description of each behaviour is presented in the method.

D7		Categories									
		1	2	3	4	5	6	7	8	9	10
VI-VI	Cmp 1	80.1 (4.4)	3.4 (0.3)	2 (0.4)	3.4 (1.1)	5.8 (0.6)	0.6 (0.1)	4.8 (4.1)			
	Cmp 2	63.8 (5.5)	3.5 (1.0)	1.9 (0.2)	0	12.9 (1.4)	0.7 (0.6)	17.2 (3.9)	0	0	0
									0.0	0.0	0.0
Vi-sigVI	Cmp 1	87.5 (1.1)	3.4 (0.6)	2 (0.1)	0.0	4.4 (1.5)	0.2 (0.2)	2.3 (0.2)			
	Cmp 2	0.8 (0.7)	0	0	3.3 (1.7)	30.7 (14.4)	0.3 (0.2)	35.2 (5.8)	0	29.3 (9.4)	0.5 (0.5)
VI-EXT	Cmp 1	69.1 (10.7)	4.7 (1.5)	2.8 (0.6)	0.0	8 (7.1)	1.4 (0.4)	6 (1.3)	7.9 (3.6)	0.0	0.0
	Cmp 2	0.0	0.0	0.0	0.0	47.4 (7.7)	11.6 (4.4)	11 (7.6)	0.0	0	29.4 (4.5)
VI-VI	Cmp 1	83.3 (5.4)	4.3 (0.2)	1.8 (0.3)	1.2 (1.3)	8.2 (5.4)	1.0 (0.3)	0.3 (0.3)	0	0	0
	Cmp 2	65.2 (2.1)	4.7 (0.8)	3.2 (0.3)	0.2 (0.3)	18.4 (2.2)	1.5 (0.6)	1.2 (0.7)	0.0	1.8 (1.0)	4.0 (0.7)
VI-VT	Cmp 1	86.8 (1.1)	3.2 (0.6)	3.0 (0.9)	0.8 (0.3)	5.1 (0.8)	0.5 (0.6)	0.7 (0.3)	0	0	0
	Cmp 2	14.7 (6.4)	0.0	0.0	3.5 (0.7)	21.2 (1.4)	2.0 (0.2)	22.7 (1.7)	0.1 (0.1)	35.8 (6.2)	0
VI-EXT	Cmp 1	86.1 (3.9)	6.0 (2.7)	2.7 (0.5)	0.1 (0.2)	4.9 (6.9)	0.1 (0.1)	0.0	0.2 (0.3)	0	0
	Cmp 2	2.6 (1.3)	0.0	0.0	1.7 (2.4)	53.4 (2.3)	5.1 (1.0)	10.8 (2.1)	1.3 (1.9)	12.1 (1.3)	12.9 (7.6)

Behaviour Key

1: Key Pecking
2: Time to start
3: Post reinforcement pause
4: Bopping on Hopper
5: Not orienting
6: Scratching
7: Strutting interface
8: Bopping inactive hopper
9: Strutting tin
10: Frustration

Appendix C

Table 4: Percentage of time D8 spent engaged in behaviours during the last three sessions of each condition. Component 1 is the constant (green key) component, component 2 is the varied (red key) component. Standard deviations across the three sessions averaged is presented in the brackets. Description of each behaviour is presented in the method.

D8		Categories									
		1	2	3	4	5	6	7	8	9	10
VI-VI	Cmp 1	43.7 (7.5)	2.1 (0.5)	3.7 (0.3)	0	42.1 (3.2)	2.2 (0.3)	6.2 (4.6)	0	0	0
	Cmp 2	34.1 (5.6)	9 (0.8)	2.2 (0.7)	0.0	22.3 (13.9)	0.7 (0.3)	31.6 (9.1)	0	0	0
Vi-sigVI	Cmp 1	46.6 (6.8)	3 (0.9)	2.3 (0.1)	0.4 (0.4)	42.5 (5.1)	1.2 (0.5)	3.9 (1.8)	0.0	0.0	0.0
	Cmp 2	0.3 (0.3)	0	0	2.3 (0.8)	78.4 (8.9)	1.9 (0.9)	16.6 (10.8)	0.3 (0.1)	0.4 (0.2)	0
VI-EXT	Cmp 1	66.5 (21.7)	9.6 (4.7)	3 (0.6)	0.1 (0.2)	13.9 (16.1)	0.6 (0.2)	6.4 (2.0)	0.0	0.0	0.0
	Cmp 2	0.0	0.0	0.0	0.0	14.4 (8.3)	3.5 (1.9)	18.2 (7.3)	0.0	44.7 (16.6)	19.1 (4.1)
VI-VI	Cmp 1	79.9 (6.3)	3.8 (0.9)	3.2 (0.8)	3.6 (6.2)	8.3 (2.5)	0.4 (0.7)	0.8 (1.4)	0	0	0
	Cmp 2	77.8 (2.2)	4.5 (0.2)	2.1 (0.4)	0.0	12.5 (3.6)	1.2 (1.1)	1.3 91.7)	0.0	0.7 (0.3)	0
VI-VT	Cmp 1	68.4 (6.0)	3.4 (0.6)	1.9 (0.7)	0.0	21.5 (7.2)	0.9 (0.2)	3.9 (1.6)	0	0	0
	Cmp 2	5.3 (2.7)	0.0	0.0	2.6 (0.9)	62.4 (17.9)	1.3 (1.1)	21.1 (10.8)	0.4 (0.5)	6.9 (3.6)	0
VI-EXT	Cmp 1	65.7 (7.4)	3.9 (0.7)	3.1 (0.2)	0.4 (0.2)	17.6 (2.3)	0.0	3.5 (2.9)	0.0	0.0	5.9 (2.5)
	Cmp 2	0.5 (0.2)	0.0	0.0	0.2 (0.2)	60.3 (13.4)	1.2 (0.8)	10.2 (4.8)	1.3 (0.3)	1.6 (2.0)	24.7 (20.6)

Behaviour Key

1: Key Pecking
2: Time to start
3: Post reinforcement pause
4: Bopping on Hopper
5: Not orienting
6: Scratching
7: Strutting interface
8: Bopping inactive hopper
9: Strutting tin
10: Frustration